Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 534 140 A1

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 92114326.9

(51) Int. Cl.5: F21V 8/00

(22) Date of filing: 21.08.92

(30) Priority: 22.08.91 JP 233799/91
04.09.91 JP 250327/91
27.09.91 JP 275022/91
29.10.91 JP 308196/91

(43) Date of publication of application:
31.03.93 Bulletin 93/13

(84) Designated Contracting States:
DE GB IT NL

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(54) **Backlighting device.**

(57) In a backlighting device for use with display panels that comprises a light conducting plate (1) made of a light-transmissive material, one of the major faces of said light conducting plate being provided with a light diffusing capability (6) and covered with a specular or light diffusing/reflecting plate (3), and a linear light source (4) provided in proximity to the end portion of at least one side of said light conducting plate, the improvement wherein at least one sheet (7) that is made of a light-transmissive material and that has a multiple of raised structures having straight ridgelines (8) at minute intervals on the same side in such a manner that the ridgelines (8) are substantially parallel to one another or at least one sheet that is made of a light-transmissive material and that has a multiple of pyramidal or conical projecting structures at minute intervals on the same side, said projecting structures having portions of such a shape that the vertical angles are substantially the same, is provided on the exit face of the light conducting plate (1) in such a way that either type of structures face outward.

FIG. 3(b)

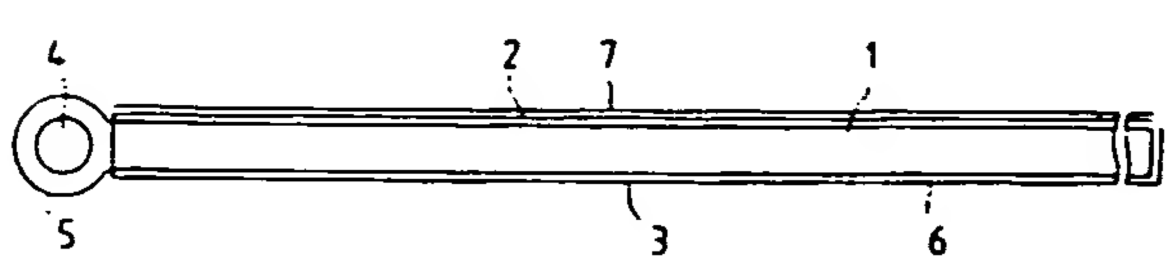
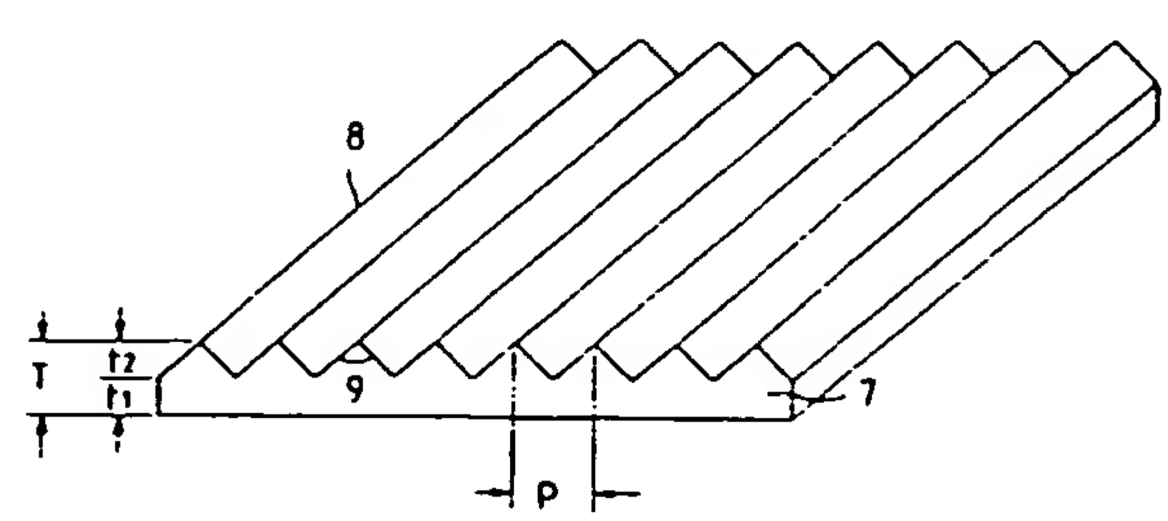


FIG. 5(a)



EP 0 534 140 A1

Background of the Invention

Field of Industrial Utility

The present invention relates to a backlighting device for liquid-crystal panels that illuminates transmissive or semi-transmissive panels from the rear side.

Prior Art

Thin liquid-crystal displays provided with a backlighting mechanism that allows easy viewing of information on the screen are used with recent versions of laptop or book type word processors and computers. The backlighting mechanism in common use adopts a "single lamp edge lighting" method in which a linear light source such as a fluorescent tube is provided at one end portion of a transmissive light conducting plate as shown in Fig. 1(a), or a "dual lamp edge lighting" method in which a linear light source such as a fluorescent tube is provided at two end portions of a transmissive light conducting plate as shown in Fig. 2(a). As shown in Figs. 1(b) and 2(b), one surface of the light conducting plate operating on those edge lighting methods is often covered partially with a light diffusing material and the thus covered area is almost entirely covered with a light diffusing/reflecting plate.

In addition, as is often the case today, backlighting devices are driven with a battery and a further improvement in the efficiency of power to luminance conversion is desired. To meet this need, it has been proposed that a light reflector covering the linear source be provided with a reflecting plate having high reflectance or that the area of the light conducting plate partially covered with the light diffusing material be provided with a reflecting plate having high reflectance.

The methods described above achieve some improvement in the efficiency of power to luminance conversion but it is still insufficient and an even better improvement is desired.

Summary of the Invention

An object, therefore, of the present invention is to provide a backlighting device that has a high efficiency of power to luminance conversion and which hence is capable of achieving high luminance.

The present inventors conducted various studies in order to solve the aforementioned problems of the prior art and found that when a transmissive sheet having a multiple of structures of a specified kind was provided on the exit face of a transmissive material (light conducting plate) given light diffusing ability, the directivity of light issuing from the exit face was enhanced to realize a backlighting device having a higher efficiency of power to luminance conversion in directions near a line dropped perpendicular to the exit face.

It was also found that a light conducting plate given a specified kind of light diffusing quality could produce a uniform luminance distribution.

According to its first aspect, the present invention provides a backlighting device for use with display panels that comprises a light conducting plate made of a light-transmissive material, one of the major faces of said light conducting plate being provided with a light diffusing capability and covered with a specular or light diffusing/reflecting plate, and a linear light source provided in proximity to the end portion of at least one side of said light conducting plate, characterized in that at least one sheet that is made of a light-transmissive material and that has a multiple of raised structures having straight ridgelines at minute intervals on the same side in such a manner that the ridgelines are substantially parallel to one another or at least one sheet that is made of a light-transmissive material and that has a multiple of pyramidal or conical projections at minute intervals on the same side, said projections having portions of such a shape that the vertical angles are substantially the same, is provided on the exit face of the light conducting plate in such a way that the sides intersecting on the ridgelines or the projections face outward.

According to its second aspect, the present invention provides a backlighting device for use with display panels that comprises a light conducting plate made of a light-transmissive material and a linear light source provided in proximity to the end portion of one or both sides of said light conducting plate, said light conducting plate having a light diffusing capability such as to produce a substantially constant haze value on the plate surface, all surfaces of said light conducting plate being covered with a light reflecting plate or film except at least on said end portion of the side which is in proximity to the linear light source and on the exit face.

Brief Description of the Drawings

Fig. 1(a) is a perspective view of a backlighting device operating on the "single lamp edge lighting" method;

Fig. 1(b) is a cross-sectional view of the backlighting device shown in Fig. 1(a);

Fig. 2(a) is a perspective view of a backlighting device operating on the "dual lamp edge lighting" method;

Fig. 2(b) is a cross-sectional view of the backlighting device shown in Fig. 2(a);

Fig. 3(a) is a perspective view of a backlighting device according to an embodiment of the "edge lighting" method in which a light source is provided at an end portion of a light conducting plate;

Fig. 3(b) is a cross-sectional view of the device;

Fig. 4(a) is a perspective view of a backlighting device according to another embodiment of the "edge lighting" method in which a light source is provided at both end portions of a light conducting plate;

Fig. 4(b) is a cross-sectional view of the device.

Fig. 5(a) is a perspective view showing a sheet having linear prism-like structures that is to be used in an embodiment of the present invention;

Fig. 5(b) is a plane figure showing a sheet having triangular prism structures that is to be used in an another embodiment of the present invention;

Fig. 5(c) is a cross-sectional view of the sheet shown in Fig. 5(b).

Fig. 6 is a diagram showing how a luminance measurement was conducted to evaluate the performance of the backlighting device of the present invention; and

Figs. 7 to 11 are graphs plotting the luminance distribution curves obtained in Examples and Comparative Examples.

Detailed Description of the Preferred Embodiments

The present invention is described below in detail with reference to the accompanying drawings.

Shown by 1 is the light conducting plate which may be made of any material that is capable of efficient light transmission, as exemplified by quartz, glass, light-transmissive natural or synthetic resins such as acrylic resins. To impart light diffusing ability to the light conducting plate, one may apply a light-diffusing material (indicated by 6 is Figs. 3(b) and 4(b)) to part of the plate surface. Examples of the light diffusing material include paints and printing inks that contain titanium white, magnesium carbonate, barium sulfate, magnesium oxide and other pigments that have higher refractive indices and diffusion reflectances than the material of which the light conducting plate is made.

Paints and printing inks that contain silica or other materials that have refractive indices either substantially equal to or lower than those of the material of which the light conducting plate is made may also be used as long as silica or other materials have such a shape as to effect optical light diffusion.

Those light diffusive materials or silica or the like are screen-printed or otherwise printed in dots or strips on the surface of the light conducting plate. Alternatively, the intended light diffusing capability may be provided by roughening the surface of the light conducting plate and this can be accomplished by directly forming small holes or grooves in strips in the surface of the conducting plate or by providing small projections on that surface.

When imparting light diffusing quality to the conducting plate by one of the methods described above, the profile of that quality is preferably such that the density of the light-diffusing areas (e.g. the number of printed dots per unit area) will increase with the distance from the light source) and this is preferred from the viewpoint of a uniform luminance distribution.

Shown by 4 is the linear light source. In a preferred embodiment, this linear light source is covered with a reflector 5 in such a way as to provide a certain clearance between the outer surface of the light source and the inner surface of said reflector. The reflector has a slit formed in the surface through which incident light from the linear light source is admitted into an end portion of the light conducting plate. The light source 4 is provided in proximity to at least one end face portion of the light conducting plate in such away that its central axis is substantially parallel to either end face of the light conducting plate.

The above-mentioned "edge lighting" method is higher than a "under lighting" method, in which a light source is disposed under a transmissive light conducting plate, in a light utilizing rate due to a following reason. Although it is possible to maximally utilize a reflecting light within the light conducting plate with a reflecting plate or the like in the "edge lighting" method, the "under lighting" method must have a shading plate into which a part of light is absorbed.

The linear light source 4 may be selected from among various types including a fluorescent tube, a tungsten incandescent tube, an optical rod and an array of LEDs, and a fluorescent tube is preferred. From the viewpoint of power saving, it is preferred that the length of the portion capable of uniform light emission except the electrode portion is substantially equal to the length of the end portion of the light conducting plate in proximity to that emitting portion.

The specular or light diffusing/reflecting plate (indicated by 3 in Figs. 3(b) and 4(b)) is provided in such away as to cover substantially all part of the face of the light conducting plate that has been provided with light diffusing capability. If desired, the same plate may be provided in such a way as to additionally cover almost all part of the other end face portion of the light conducting plate which is not in proximity to the linear light source, and this is preferred from the viewpoints of efficient utiliza-

-tion of light and the accomplishment of uniform areal light emission. In this case, the layer of a material such as air that has a lower refractive index than the material of which the light conducting plate is made may be provided between the light conducting plate and the reflecting plate in a thickness of at least equal to that of a monolayer of air, preferably no more than 2 mm, and this is preferred for the purpose of enhancing the efficiency of light utilization.

Shown by 7 is a sheet made of a light-transmissive material (which is hereunder referred to simply as "sheet") and it has a multiple of parallel straight ridgelines or pyramidal or conical projections that are formed at minute intervals on the same side. The sheet is provided in such a way that the sides intersecting at the ridgelines or the projections face outward (toward the side opposite the side facing the light conducting plate). The sheet changes the directivity of the light issuing from the exit face of the backlighting device in such a way that the directivity in directions close to a line dropped perpendicular to the exit face is enhanced. When using a sheet having the straight ridgelines described above, it may be provided in such a way that it is parallel or perpendicular to the central axis of the linear light source. In a more preferred embodiment, the sheet is provided in such a way when the backlighting device of interest is assembled in a display unit, in particular a liquid-crystal display unit, the straight ridgelines described above will lie parallel to the lateral direction of the level of vision and this layout is preferred in view of the visual contrast characteristics of the system.

In the present invention, one or more of the sheets under discussion are used; if desired, the light diffusing plate (indicated by 2 in Figs. 3(b) and 4(b)) may be provided in order to make undiscernible the dotted pattern of light diffusing function, say, the light diffusing material (indicated by 6), which is imparted to the surface of the light conducting plate. With this arrangement, the relative increase in luminance as measured in the direction of a normal to the surface of the light conducting plate will be almost same. If the light diffusing plate is provided outside the sheet, the relative increase in luminance as measured in the normal direction will decrease a little to reduce the directivity of light; however, this arrangement offers the advantage that when the backlighting device of interest is used with a liquid-crystal display unit, the development of a moiré pattern is inhibited.

If the sheet is to be placed direct on the surface of the light conducting plate, the two members are preferably in such a state that they are not in optical with contact each other. To meet this requirement, a member serving as a spacer may be provide between the sheet and the light conducting plate and an example of such a spacer member is the layer of a material, such as air, that has a lower refractive index than the material of which the light conducting plate is made; if this layer is provided in a thickness of at least equal to that of a monolayer of that low-index material, preferably no more than 2 mm, the formation of bright spots on the light emitting surface is sufficiently inhibited to provide a uniform luminance distribution.

As already mentioned, the first aspect of the present invention is characterized in that a sheet that is made of a light-transmissive material and which has a configuration that satisfies the certain specified condition is provided on the exit face of the backlighting device.

Said specified condition to be satisfied by the present invention is further elaborated below. The sheet described above (indicated by 7) is in no way limited as long as it is made of a light-transmissive material and examples include polyesters such as polymethacrylate esters, polycarbonates, polyvinyl, polyamides and polyethylene terephthalate (PET), poly-α-olefins, cellulosic resins and glass. The sheet may be made of the same material as the raised structures or pyramidal or conical projections. Alternatively, the raised structures or pyramidal or conical projections may be formed on a base film from dissimilar materials such as a uv curable resin.

An example of the sheet that can be used in the first aspect of the present invention is one having raised structures that are provided on the exit face of the light conducting plate and which have parallel straight ridgelines. As shown in Fig. 9, the raised structures are shaped like "prisms" having optical planes; the ridgelines (indicated by 8 in Fig. 5(a)) on which two optical planes intersect each other are straight and a multiple of lineal prisms that are parallel to one another are present in the same plane at minute intervals (indicated by P in Fig. 5(a)). Those ridgelines which are formed on the sheet have portions of such a shape that the vertical angles are substantially the same and this means that when the prisms are cut through the vertex under the same conditions, their vertical angles are essentially the same.

For the purposes of the present invention, each of the vertical angles of the ridgelines on the sheet (as indicated by 9 in Fig. 5(a)) is preferably in the range of 70 to 150 degrees. The more preferred range of vertical angles is dependent on the refractive index of the material of the sheet to be used and on the luminous intensity distribution characteristics of the flat light emitter to be used. Consider, for example, the case where a material having high refractive index (i.e., polycarbonate;

n = 1.59) is used; in this case, the vertical angle of interest is preferably in the range of 90 to 110 degrees and if it exceeds 150 degrees, the effectiveness of the present invention is reduced; if the luminous intensity distribution characteristics are such that the light emerging from the flat light emitter is substantially concentrated within the range of 45 degrees from the direction of a line dropped perpendicular to the exit face, the vertical angle of interest is preferably in the range of 90 to 140 degrees.

A cross section of the raised structures on the sheet as taken in a direction perpendicular to the longitudinal axis is triangular and for maximizing the effectiveness of the present invention, it is particularly preferred to use raised structures having a cross section that is substantially an isosceles triangle which is equal in the length of two sides intersecting at the vertex of each ridgeline. In order to insure that the distance between adjacent straight raised structures formed on the sheet are difficult to discern under the light emitted from their surface, the distance between the ridgelines of adjacent parallel structures is preferably 10 to 100 μm. The thickness of that part of the sheet which is occupied by the raised structures (as denoted by t2 in Fig. 5(a)) is determined by the vertical angle of ridgelines and by the distance between adjacent ridgelines. It is at least necessary to provide a certain thickness for maintaining a number of raised structures at minute intervals and parallel to one another; this thickness denoted by t1 is preferably as small as possible in order to insure high transmittance of light rays and to realize a thin backlighting device. However, from the viewpoint of workmanship in the manufacture of sheets and in order to insure adequate strength, the total thickness (T) of the sheet is typically 10 to 3000 μm, preferably 50 to 1000 μm. To achieve better results in the present invention, the raised structures to be formed on the same side are preferably shaped identically.

Another example of the sheet that can be used in the first aspect of the present invention is one having projections that are to be provided on the exit face of the light conducting plate and which are shaped like "prisms" having at least two optical planes. The projections are either in the form of pyramids such as a triangular prism and a quadrangular prism or in a conical form as shown in Fig. 5 (b)(c). The projections to be formed on the sheet have portions of such a shape that their vertical angles are substantially the same and this means that the vertical angles of vertex-including cross sections that are obtained under the same conditions are substantially the same. The expression "having portions of such a shape that the vertical angle are substantially the same" as used hereinabove should be taken broadly and allows for the case where pyramids of different kinds (n ≥ 3; n is the number of sides forming a polygonal base) or cones are present in combination; even in that case, the conditions of the present invention are satisfied if the kind and number of pyramids (n ≥ 3) or cones present in any area (e.g. a circle of 30 mm°) of the projecting side of the sheet are nearly equal to the kind and number of pyramids (n ≥ 3) or cones present in another area. For better effectiveness, it is preferred to use projections of identical shape and vertical angle. To further enhance the effectiveness of the present invention, it is particularly preferred to bring the surfaces of projections, within the limits of manufacturing tolerances, to optical planes (if the projections are pyramidal) and to optical curved surfaces (if the projections are conical); this means the asperities on the surfaces of projections should be made smaller than the operating wavelength of light within the limits of tolerances.

For the vertical angle of projections on the sheet, the distance between the vertices of adjacent projections, the thickness of the projecting part of the sheet and other design parameters, see the discussion already made concerning the straight raised structures.

The method of shaping the sheets to be used in the present invention is in no way limited and various methods can be adopted, including molding with a hot press, embossing, casting, UV curing and chemical treatment. Because of process limits in the manufacture of sheets, a certain degree of sag will occur in the ridgelines but it is acceptable as long as it is within the range where the effectiveness of the present invention is insured.

A liquid-crystal display presents a lower contrast as the angle the line of vision forms with a line dropped perpendicular to the screen increases; therefore, the luminance as measured in directions close to the normal line defined above is held important in practical applications. This is all the more important for a viewfinder which is only looked at in directions parallel to the line normal to the image plane.

In the present invention, a sheet having a number of parallel structures as arranged at minute intervals on the side where outgoing light rays emerge is provided on the exit face of the backlighting device as already described above and this creates directivity of light. The improved light directivity is apparent from the following typical phenomena: first, the luminance of light issuing from the exit face as measured in a direction substantially parallel to a line dropped perpendicular to that exit face is higher than in the case where none of the sheets described above are provided;

second, the luminance as measured in a direction at an angle of, say, 40 degrees with a line dropped perpendicular to the exit face is significantly lower than the value as measured in a direction substantially parallel to that normal line (in a typical case, the drop is almost 50% of the reference value).

According to the other aspect of the present invention, there is provided a backlighting device using a light conducting plate that has such a light diffusing capability as to provide a substantially constant haze value over the plate surface, which is covered with a reflecting plate or film.

The expression "having a substantially constant haze value" means that the light conducting plate has a substantially constant haze value over almost all surface of the plate and it does not contemplate an embodiment in which the haze value is intentially changed as by varying the light diffusing capability of the plate surface with the distance from the light source (see the description of the first aspect of the invention). Therefore, unintentional variations in haze value that will occur when imparting the light diffusing capability are taken to be included within the scope of "being substantially constant" for the purposes of the present invention.

In a preferred embodiment, the haze value to be exhibited by the light conducting plate ranges from 0.5 to 50%. The effectiveness of the present invention will decrease if the haze value is outside this range. The term "haze value" as used herein means the value that is obtained by measuring on a major surface of the light conducting plate in accordance with JIS K 7105.

If one major surface of the light conducting plate is rendered to satisfy the haze condition set forth above, light incident at an end portion of the plate will not immediately emerge from the exit face but will instead undergo repeated internal reflection within the plate; in addition, light emerging from the conducting plate at the surfaces other than the exit face is returned to the interior of the plate by means of the reflecting plate which covers those surface other than the exit face of the conducting plate. As a result, the light incident at an end portion of the conducting plate is confined within the plate for a sufficient period to become uniform, thereby contributing to the manufacture of a backlighting device that features a uniform luminance distribution.

Advantages of the Invention

The backlighting device of the present invention is fairly compact, provides satisfactory luminance and can be operated with a high efficiency of power to luminance conversion in a direction parallel to a line dropped perpendicular to the exit face.

Examples

Comparative examples and working examples of the present invention are described below in order to further illustrate the present invention. A rectangular light conducting plate (225 mm × 127 mm; made of polymethyl methacrylate PMMA) having a thickness of 2 mm (see Fig. 3) was provided. A cold-cathode fluorescent tube (a normal tube of Harrison Denki K.K.) with a diameter of 4.8 mm was positioned in proximity to one of its shorter sides. The fluorescent tube was enclosed with a cylindrical aluminum reflector that was laminated with a lining of light diffusing film and which had a slit 2 mm wide in contact with the light conducting plate in such a way that light emerging through the slit would be admitted into the plate from one shorter side. A light diffusing material (a paint containing titanium white) was applied over the surface of the light conducting plate by screen-printing a pattern of circular dots on a pitch of 1.2 mm in such a way that the coverage with the light diffusing material would be 6% at the point for a minimum value (on the side facing the cold-cathode fluorescent tube) and 80% at the point for a maximum value, with the coverage being gradually increased in the intermediate area.

A light diffusing film (0.1 mm thick; D-204 of Tsujimoto Denki Seisakusho) was provided in the exit face of the light conducting plate. All surface of the light conducting plate except the entrance and exit faces were covered with another light diffusing film (125 μm thick; diffusion reflectance = 83%; product of ICI Limited).

The areal luminance as produced when the cold-cathode tube was driven at a constant current with an alternating voltage (30 kHz) being applied from an inverter was measured with a luminance meter (Topcon BM-7) at a view angle of 2 degrees in a direction parallel to a line dropped perpendicular to the exit face, with the distance from the exit face to the luminance meter being 40 cm; the result was 192 cd/m^2 (Comparative Example 1).

A backlighting device was constructed and operated as in Comparative Example 1 except that a commercial polycarbonate sheet 360 μm thick that had a multiple of parallel linear prisms having a vertical angle of 90 degrees and which was worked to have a distance of 360 μm between adjacent ridgelines on linear prisms was provided on the exit face of the light diffusing film in such a way that the prisms would face outward. The luminance as measured on this backlighting device as in Comparative Example 1 was 307 cd/m^2 (Example 1).

A backlighting device was constructed and operated as in Example 1 except that the polycar-

bonate sheet was provided in the exit face of the light diffusing film in such a way that the prisms would face inward. The luminance as measured on this backlighting device as in Example 1 was 15 cd/m² (Comparative Example 2). Another backlighting device was constructed and operated as in Example 1 except that the vertical angle of linear prisms was changed to 70 degrees. The luminance as measured on this backlighting device as in Example 1 was 245 cd/m² (Example 2). Yet another backlighting device was constructed and operated as in Example 1 except that the vertical angle of linear prisms was changed to 100 degrees. The luminance as measured on this backlighting device as in Example 1 was 330 cd/m² (Example 3).

A backlighting device was constructed and operated as in Comparative Example 1 except that a sheet comprising a 50-μm thick PET base film that had a multiple of linear projections formed on it from a uv curable resin (acrylic resin) by printing was provided on the exit face of the light diffusing film in such a way that the linear projections would face outward: the base of each projection had a diameter of 50 μm and the height of each projection as measured from its base to top was 25 μm, with the distance between adjacent projections being 50 μm. The luminance measured on this backlighting device as in Comparative Example 1 was 235 cd/m² (Example 4).

Another backlighting device was constructed and operated as in Comparative Example 1 except that a sheet having a total thickness of 400 μm that was worked to have a multiple of projections in the from of a quadrangular prism having a vertical angle of 90 degrees in such a way that the distance between adjacent vertices of projections would be 400 μm was provided on the exit face of the flat light emitter in such a way that the projections would face outward. The luminance as measured on this backlighting device as in Comparative Example 1 was 322 cd/m² (Example 5). Yet another backlighting device was constructed and operated as in Example 5 except that the sheet was provided on the exit face of the flat light emitter in such a way that the projections would face inward. The luminance as measured on this backlighting device as in Example 5 was 23 cd/m² (Comparative Example 3). As is clear from these results, the first aspect of the present invention is characterized in that a sheet that is made of a light-transmissive material and on which a multiple of structures having portions of such a shape that the vertical angles are substantially the same are formed on the same side at minute intervals is provided on the exit face of a flat light emitter in such a way that the projecting side will face outward, and the effectiveness of the present invention is not exhibited if the sheet is provided on the exit face of the flat light emitter in such a way that the projecting side will face inward.

Two additional backlighting devices were constructed and operated as in Example 5 except that the vertical angle of each projection was changed to 70 degrees (Example 6) and 120 degrees (Example 7). The results of luminance measurement that was conducted on those devices as in Example 5 were 263 cd/m² and 359 cd/m², respectively. Another backlighting devices was constructed and operated as in Example 5 except that a multiple of convex lenses were formed of a uv curable resin by printing on a 50-μm thick PET base film in such a way that the base of each convex was 50 μm and the height of each projection as measured from its base to top was 25 μm, with the distance between adjacent projections being 50 μm. The luminance as measured on this backlighting device as in Example 5 was 258 cd/m² (Example 8).

To investigate the luminous intensity distribution characteristics of various samples of backlighting device, areal luminance as produced when the cold-cathode tube was driven at a constant current with an alternating voltage (30 kHz) being applied from an inverter was measured by the experimental layout shown in Fig. 6 using a luminance meter (indicated by 10; Topcon BM-7) at a view angle of 2 degrees, with the distance from the exit face to the luminance meter being 40 cm while the angle (indicated by 11) the luminance meter formed with a line (indicated by 12) dropped perpendicular to the exit face was varied from 0 to 70 degrees in a direction perpendicular to the ridgelines of the linear projections formed on the sheet. The results of the measurement are shown in Figs. 7 and 8, from which one can see that when the backlighting device of the present invention were used, the luminance was increased to achieve a marked improvement in the directivity of light.

Another experiment was conducted in the following manner. A cold-cathode fluorescent tube (a normal tube of Harrison Denki K.K.) with a diameter of 4.1 mm was positioned in proximity to both of the longer sides of a rectangular light conducting plate (made of PMMA measuring 255 mm × 157 mm) having a thickness of 8.0 mm. The fluorescent tube was enclosed with a silver (Ag) film having a slit 8 mm wide in contact with the light conducting plate in such a way that light emerging through the slit would be admitted into the plate from both longer sides. A light diffusing material (a titanium white containing paint) was applied over the surface of the light conducting plate by screen-printing a pattern of circular dots on a pitch of 1.0 mm in such a way that the coverage with the light diffusing material would be 40% at the point for a minimum value (on either side facing the cold-

~~cathode fluorescent tube) and 98%~~ at ~~the point~~ for a maximum value, with the coverage being gradually increased in the intermediate area. The surfaces of the light conducting plate other than the exit face were covered with a light diffusing/reflecting plate.

A light diffusing film (0.1 mm thick; D-204 of Tsujimoto Denki Seisakusho) was provided on the exit face of the light conducting plate. The areal luminance as produced when the cold-cathode tube was driven at a constant current with an alternating voltage (30 kHz) being applied from an inverter was measured with a luminance meter (Topcon BM-7) at a view angle of 2 degrees in a direction parallel to a line dropped perpendicular to the exit face, with the distance from the exit face to the luminance meter being 40 cm; the result was 1700 cd/m^2 (Comparative Example 4).

An additional backlighting device was constructed and operated as in Comparative Example 4 except that a commercial polycarbonate sheet 360 μm thick that had a multiple of parallel linear prisms having a vertical angle of 90 degrees and which was worked to have a distance of 360 μm between adjacent ridgelines on linear prisms was provided on the exit face of the light diffusing film in such a way that the prisms would face outward. The luminance as measured on this backlighting device as in Comparative Example 4 was 2970 cd/m^2 (Example 9).

Still another experiment was conducted in the following manner. A cold-cathode fluorescent tube (a normal tube of Harrison Denki K.K.) with a diameter of 4.1 mm was positioned in proximity to both of the longer sides of a rectangular light conducting plate (87 mm × 75 mm) having a thickness of 3.0 mm. The fluorescent tube was enclosed with a silver (Ag) film having a slit 3 mm wide in contact with the light conducting plate in such a way that light emerging through the slit would be admitted into the plate from both longer sides. A light diffusing material (a titanium white containing paint) was applied over the surface of the light conducting plate by screen-printing a pattern of circular dots on a pitch of 1.0 mm in such a way that the coverage with the light diffusing material would be 20% at the point for a minimum value (on either side facing the cold-cathode fluorescent tube) and 98% at the point for a maximum value, with the coverage being gradually increased in the intermediate area. The surfaces of the light conducting plate other than the exit face were covered with a light diffusing/reflecting plate.

A light diffusing film (0.1 mm thick; D-204 of Tsujimoto Denki Seisakusho) was provided on the exit face of the light conducting plate. The areal luminance as produced when the cold-cathode tube was driven at a constant current with an alternating voltage (30 kHz) being applied from an inverter was measured with a luminance meter (Topcon BM-7) at a view angle of 2 degrees in a direction parallel to a line dropped perpendicular to the exit face, with the distance from the exit face to the luminance meter being 40 cm; the result was 3840 cd/m^2 (Comparative Example 5).

An additional backlighting device was constructed and operated as in Comparative Example 5 except that a commercial polycarbonate sheet 360 μm thick that had a multiple of parallel linear prisms having a vertical angle of 90 degrees and which was worked to have a distance of 360 μm between adjacent ridgelines on linear prisms was provided on the exit face of the light diffusing film in such a way that the prisms would face outward. The luminance as measured on this backlighting device as in Comparative Example 5 was 5830 cd/m^2 (Example 10). Another backlighting device was constructed and operated as in Example 10 except that the vertical angle of linear prisms was changed to 70 degrees. The luminance as measured on this backlighting device as in Example 10 was 5236 cd/m^2 (Example 11).

When part of the light emerging from the flat light emitter undergoes total reflection within the prisms on the sheet before it is returned to the flat light emitter, the efficiency of the backlighting device is improved as the greater part of the surfaces of the flat light emitter other than the exit face is covered with a reflecting plate having high reflectance. To verify this effect, the following experiments were conducted. First, a backlighting device was constructed and operated as in Comparative Example 5 except that the reflecting plates covering the three non-exit faces of the light conducting plate were coated with a black paint. The luminance as measured on this backlighting device as in comparative Example 5 was 1690 cd/m^2 (Comparative Example 6). Another backlighting device was constructed and operated as in Comparative Example 6 except that a commercial polycarbonate sheet 360 μm thick that had a multiple of parallel linear prisms having a vertical angle of 90 degrees and which was worked to have a distance of 360 μm between adjacent ridgelines on linear prisms was provided on the exit face of the light diffusing film in such a way that the prisms would face outward. The luminance as measured on this backlighting device as in Comparative Example 6 was 2156 cd/m^2 (Example 12). Still another backlighting device was constructed and operated as in Example 12 except that the vertical angle of linear prisms was changed to degrees. The luminance as measured on this backlighting device as in Example 12 was 2035 cd/m^2 (Example 13).

Another series of experiments were conducted as in Comparative Example 1 except that the cov-

erage of the light conducting plate with the circular dot pattern was held constant at 6% over the entire surface of the plate. The term "coverage" as used herein means the proportion of light diffusing elements that were formed per unit area of the light conducting plate. The light diffusing capability of those element on the light conductor as measured in terms of "haze value" in accordance with JIS K 7105 was 1.4%.

A light diffusing film (0.1 mm thick; D-204 of Tsujimoto Denki seisakusho) was provided on the exit face of the light conducting plate. All surfaces of the light conducting plate except the entrance and exit faces were covered with a light diffusing/reflecting film plate (125µm thick; product of ICI Limited).

The areal luminance as produced when the cold-cathode tube was driven at a constant current with an alternating voltage (30 kHz) being applied from an inverter was measured with a luminance meter (Topcon BM-8) and the result is shown by curve a in Fig. 9 (Example 14). A luminance measurement was conducted under the same conditions except that the coverage with the light diffusing material was held constant at 7% and the result is shown by curve b in Fig. 9 (Example 15). The light diffusing capability of the light diffusing elements on the light conductor as measured in terms of haze value in accordance with JIS K 7105 was 1.5%. A luminance measurement was conducted under the same conditions except that the coverage with the light diffusing material was held constant at 9% and the result is shown by curve c in Fig. 9 (Example 16). The haze value was 1.9%.

A luminance measurement was conducted under the same conditions except that the coverage with the light diffusing material was held constant at 11% and the result is shown by curve d in Fig. 9 (Example 17). The haze value was 2.4%. Curves a to d show that the backlighting devices constructed in accordance with the present invention achieved a uniform luminance distribution.

A luminance measurement was conducted under the same conditions except that the coverage with the light diffusing material was held constant at 100% and the result is shown by curve e in Fig. 9 (Comparative Example 7). The haze value was 91%. Curve e shows that the backlighting device of Comparative Example 7 produced a very uneven luminance distribution.

A luminance measurement was also conducted under the same conditions except that no coating of light diffusing material was applied (0% coverage) and the result is shown by curve f in Fig. 9 (Comparative Example 8). The haze value was 0.3%. Curve f shows that the backlighting device of Comparative Example 8 produced very low luminance levels.

A rectangular light conducting plate (made of PMMA measuring 235 mm x 160 mm) having a thickness of 3 mm was provided. A cold-cathode tube (a 4.8-mm° normal tube of Harrison Denki K.K.) with a diameter of 4.8 mm that was 7 mm longer than the shorter side of the plate was positioned in proximity to both of its shorter sides. The cold-cathode tube was enclosed with a tubular light reflector that was laminated with a lining of light diffusing sheet and which had a slit 3 mm wide in such a way that light emerging through the slit would be admitted into the plate from both shorter sides.

A light diffusing material was applied over the surface of the light conducting plate by screen-printing a pattern of circular dots on a pitch of 1.2 mm. A screen-image carrier was prepared by CAD in such a way that the coverage with the light diffusing material would be held constant at 16% (the haze value was 3.4%).

A light diffusing film (0.1 mm D-204 of Tsujimoto Denki Seisakusho) was provided on the exit face of the light conducting plate. All surfaces of the light conducting plate except the entrance and exit faces were covered with a light diffusing/reflecting film plate (125µm thicks; produced of ICI Limited).

The areal luminance as produced when the cold-cathode tube was driven at a constant current with an alternating voltage (30 kHz) being applied from an inverter was measured with a luminance meter (Topcon BM-8) and the result is shown by curve a in Fig. 10 (Example 18).

A rectangular light conducting plate (86 mm x 65 mm) having a thickness of 3 mm was provided. A cold-cathode tube (a 4.8-mm° normal tube of Harrison Denki K.K.) with a diameter of 4.1 mm that was 12 mm longer than the longer side of the plate was positioned in proximity to both of its longer sides. The cold-cathode tube was enclosed with a tubular light reflector that was lined with a silver evaporated film and which had a slit 3 mm wide in such a way that light emerging through the slit would be admitted into the plate from both longer sides.

A light diffusing material was applied over the surface of the light conducting plate by screen-printing a pattern of circular dots on a pith of 1.0 mm. A screen-image carrier was prepared by CAD in such a way that the coverage with the light diffusing material would be held constant at 32% (the haze value was 45%).

A light diffusing film (0.1 mm; D-204 of Tsujimoto Denki Seisakusho) was provided on the exit face of the light conducting plate. All surfaces of the light conducting plate except the entrance and exit faces were covered with a light diffusing/reflecting film plate (125 thicks; product of

~~(GI Limited) of Tsujimoto Denki Seis[illegible]sho)~~

The areal luminance as produced when the cold-cathode tube was driven at a constant current with an alternating voltage (30 kHz) being applied from an inverter was measured with a luminance meter (Topcon BM-8) and the result is shown by curve a in Fig. 11 (Example 19).

A luminance measurement was conducted under the same conditions except that the coverage with the light diffusing material was held constant at 40% and the result is shown by curve b in Fig. 11 (Comparative Example 9). The haze value was 56%. One can see from curve b that the backlighting device of Comparative Example 9 produced a very uneven luminance distribution.

While the present invention has been described above with respect to a single preferred embodiment thereof, it should of course be understood that the present invention should not be limited only to this embodiment but various change or modification may be made without departure from the scope of the present invention as defined by the appended claims.

In a backlighting device for use with display panels that comprises a light conducting plate made of a light-transmissive material, one of the major faces of said light conducting plate being provided with a light diffusing capability and covered with a specular or light diffusing/reflecting plate, and a linear light source provided in proximity to the end portion of at least one side of said light conducting plate, the improvement wherein at least one sheet that is made of a light-transmissive material and that has a multiple of raised structures having straight ridgelines at minute intervals on the same side in such a manner that the ridgelines are substantially parallel to one another or at least one sheet that is made of a light-transmissive material and that has a multiple of pyramidal or conical projecting structures at minute intervals on the same side, said projecting structures having portions of such a shape that the vertical angles are substantially the same, is provided on the exit face of the light conducting plate in such a way that either type of structures face outward.

Claims

1. A backlighting device for use with display panels comprises:

   a light conducting plate made of a light-transmissive material, one of the major faces of said light conducting plate being provided with a light diffusing capability and covered with a specular or light diffusing/reflecting plate;

   a linear light source provided in proximity to the end portion of at least one side of said light conducting p[illegible] and

   a means provided on an exit face of the light conducting plate for enhancing a directivity in direction close to a line dropped perpendicular to said exit face.

2. A backlighting device for use with display panels according to claim 1, wherein said directivity enhancing means comprises at least one sheet that is made of a light-transmissive material and that has a multiple of raised structures having straight ridgelines at minute intervals on the same side in such a manner that the ridgelines are substantially parallel to one another and said structures face outward.

3. A backlighting device for use with display panels according to claim 1, wherein said directivity enhancing means comprises at least one sheet that is made of a light-transmissive material and that has a multiple of pyramidal or conical projecting structures at minute intervals on the same side, said projecting structures having portions of such a shape that the vertical angles are substantially the same, said structures facing outward.

4. A backlighting device according to claim 2, wherein each of the ridge-like structures having straight ridgelines has such a shape that a section taken perpendicular to its longitudinal axis assumes a triangular form.

5. A backlighting device according to claim 2, wherein said ridgelines has vertical angles of 70 to 150 degrees.

6. A backlighting device according to claim 3, wherein said projections has said vertical angles of 70 to 150 degrees.

7. A backlighting device according to claim 2, wherein the distance between the vertices of adjacent ridgelines is 10 to 1000 μm.

8. A backlighting device according to claim 2, wherein the distance between the vertices of adjacent projections is 10 to 1000 μm.

9. A backlighting device according to claim 2 wherein the sheets and the structures are respectively formed of dissimilar materials.

10. A backlighting device according to claim 3 wherein the sheets and the structures are respectively formed of dissimilar materials.

11. A backlighting device according to claim 1 wherein an air layer is interposed between the surface of the light conducting plate and said directivity enhancing means.

12. A backlighting device for use with display panels that comprises a light conducting plate made of a light-transmissive material and a linear light source provided in proximity to the end portion of one or both sides of said light conducting plate, said light conducting plate having a light diffusing capability such as to produce a substantially constant haze value on the plate surface, all surfaces of said light conducting plate being covered with a light reflecting plate or film except at least on said end portion of the side which is in proximity to the linear light source and on the exit face.

13. A backlighting device according to claim 12 wherein the haze value is in the range of 0.5 to 50% as measured in accordance with JIS K 7105.

FIG. 1(a) PRIOR ART

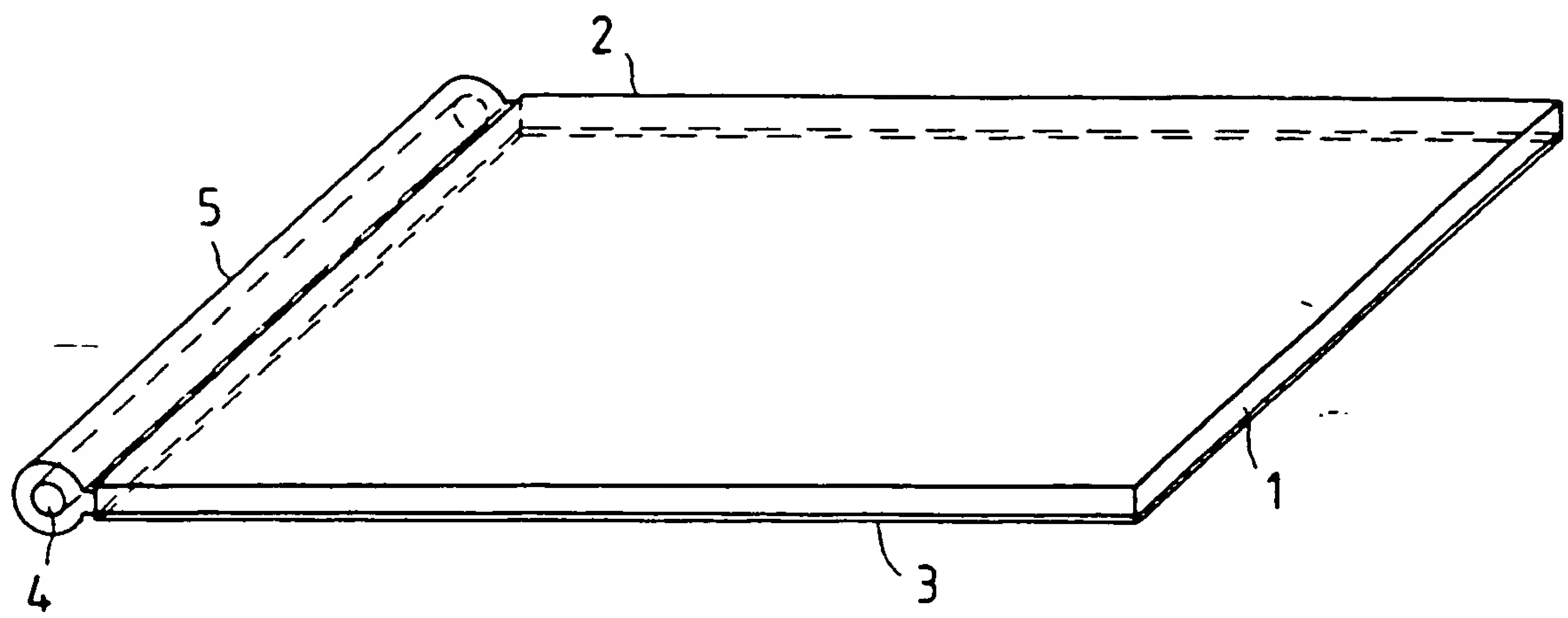


FIG. 1(b) PRIOR ART

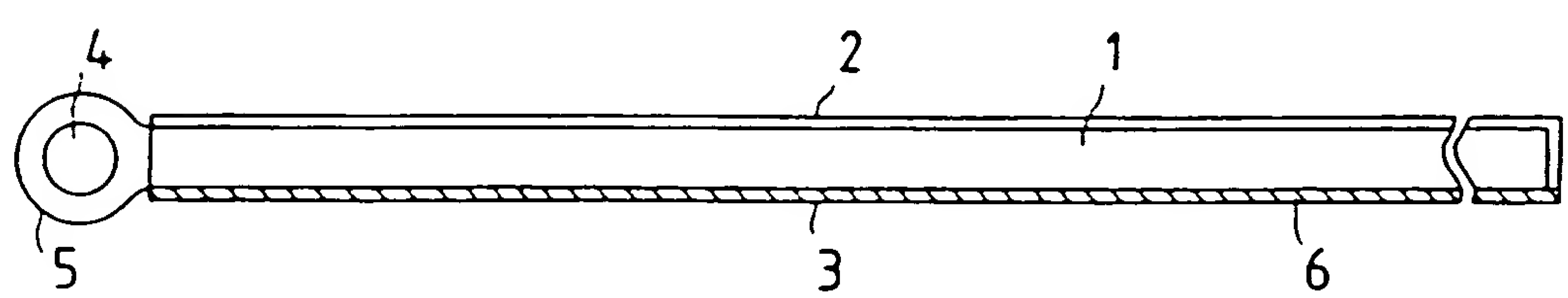


FIG. 2(a) PRIOR ART

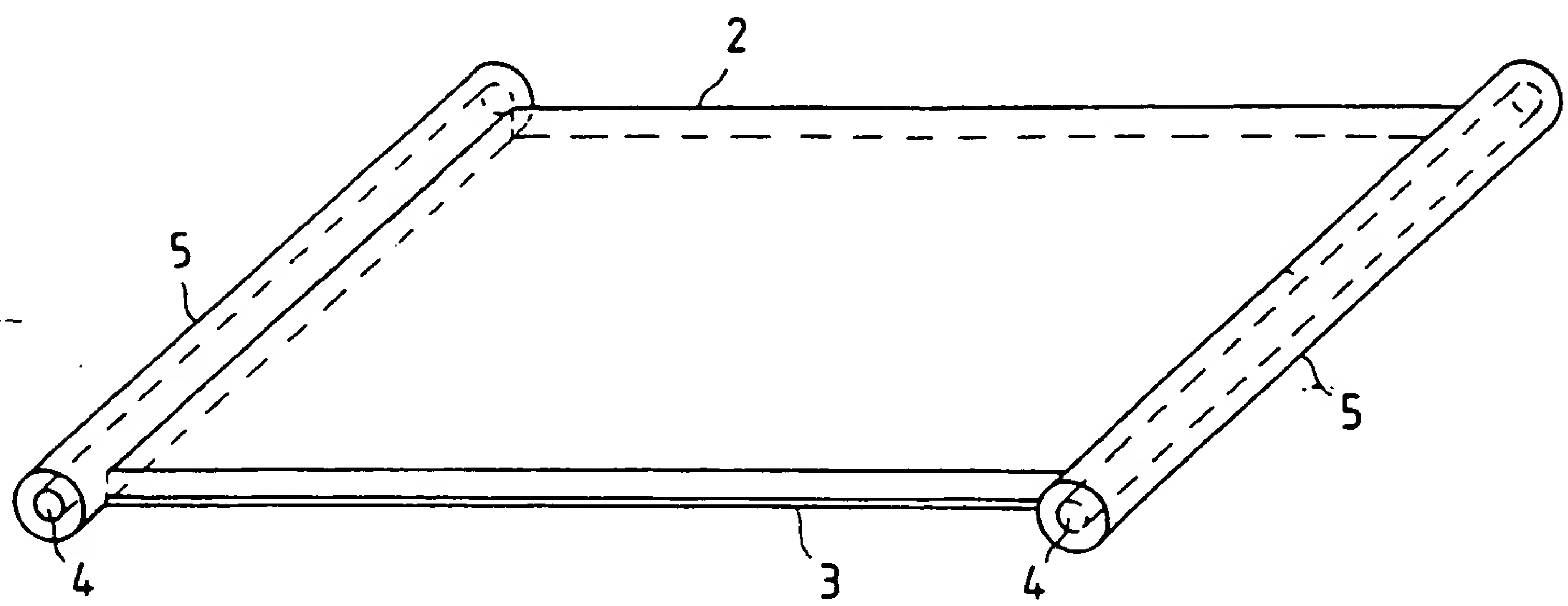


FIG. 2(b) PRIOR ART

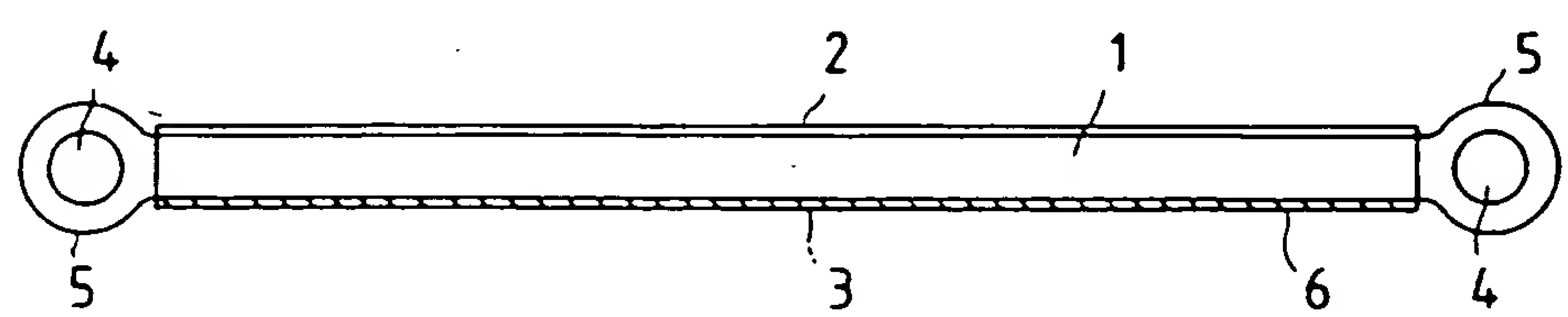


FIG. 3(a)

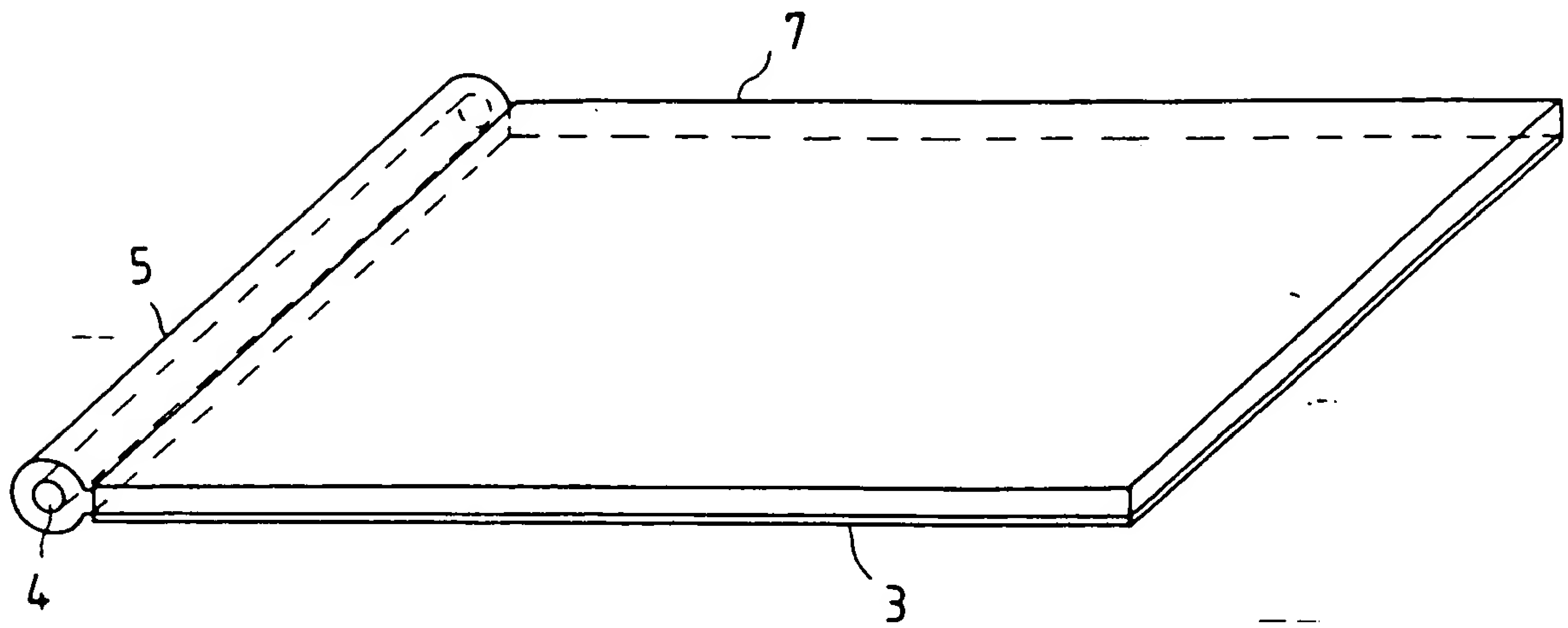


FIG. 3(b)

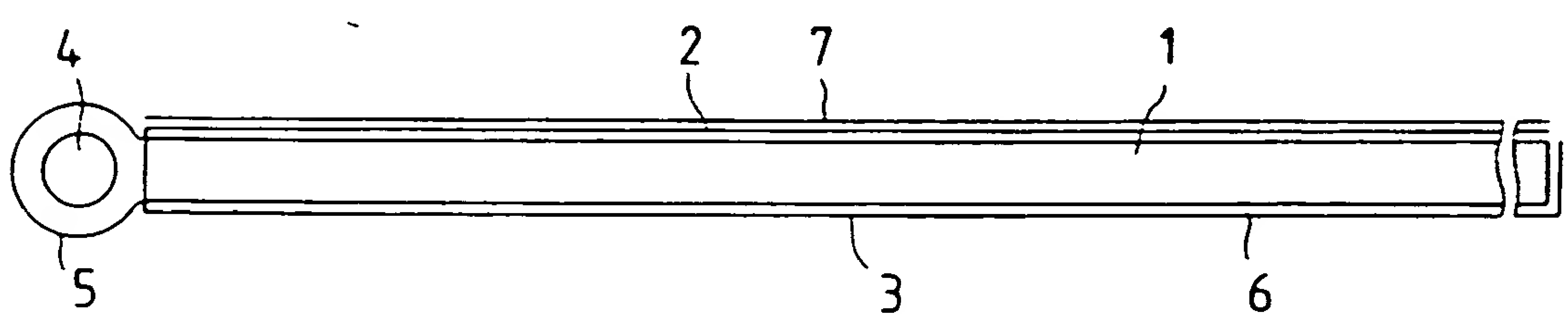


FIG. 4(a)

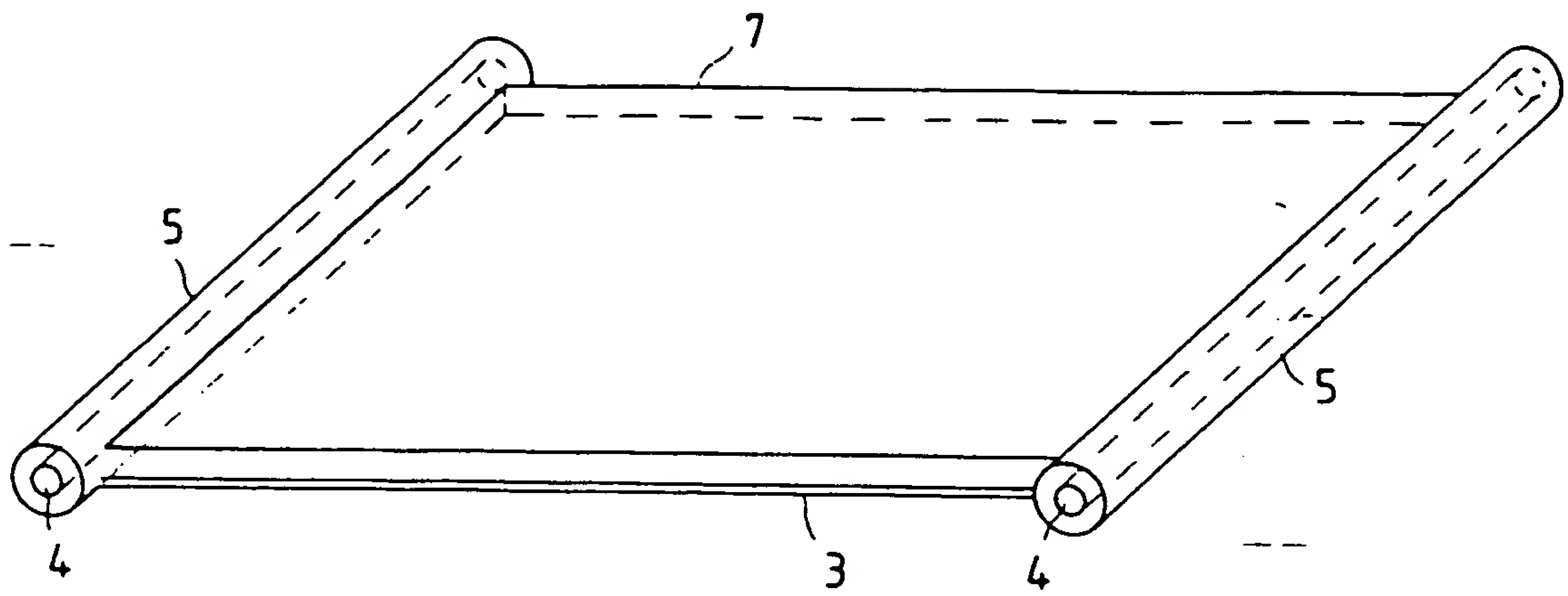


FIG. 4(b)

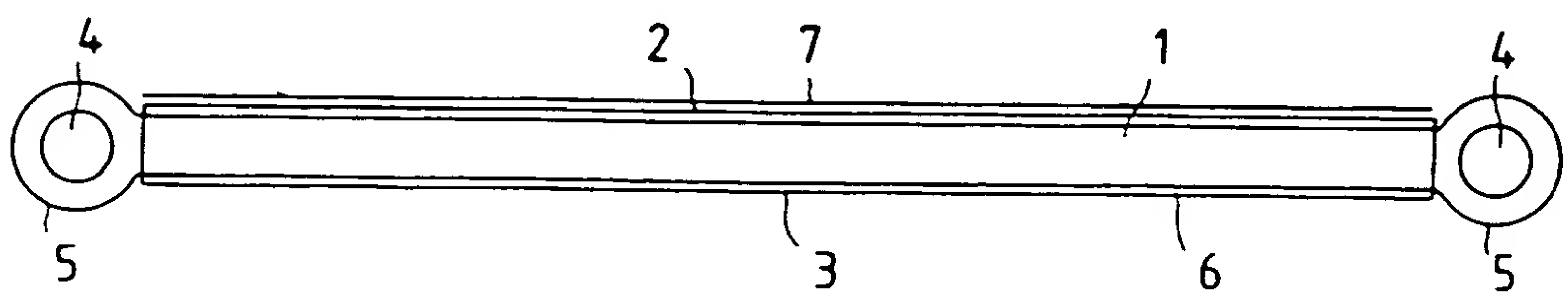


FIG. 5(a)

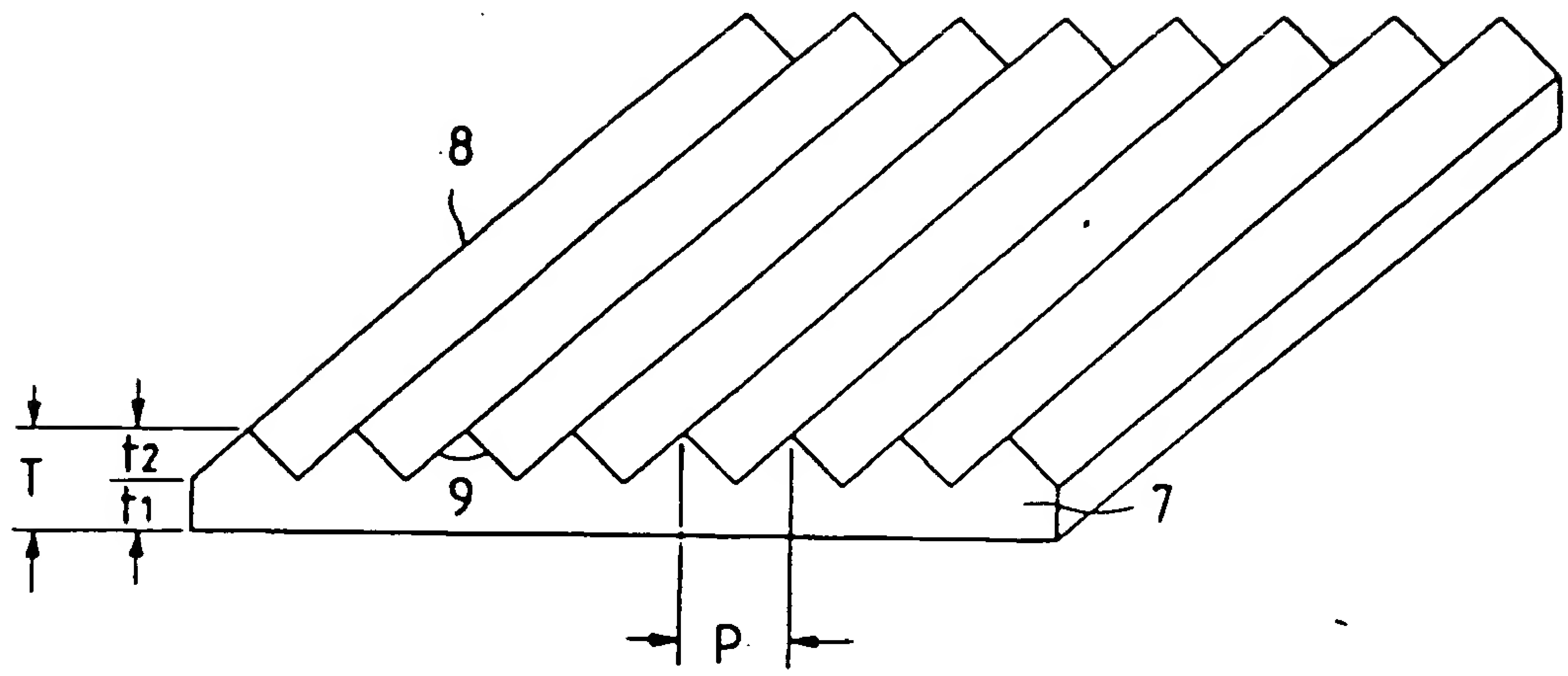


FIG. 5(b)

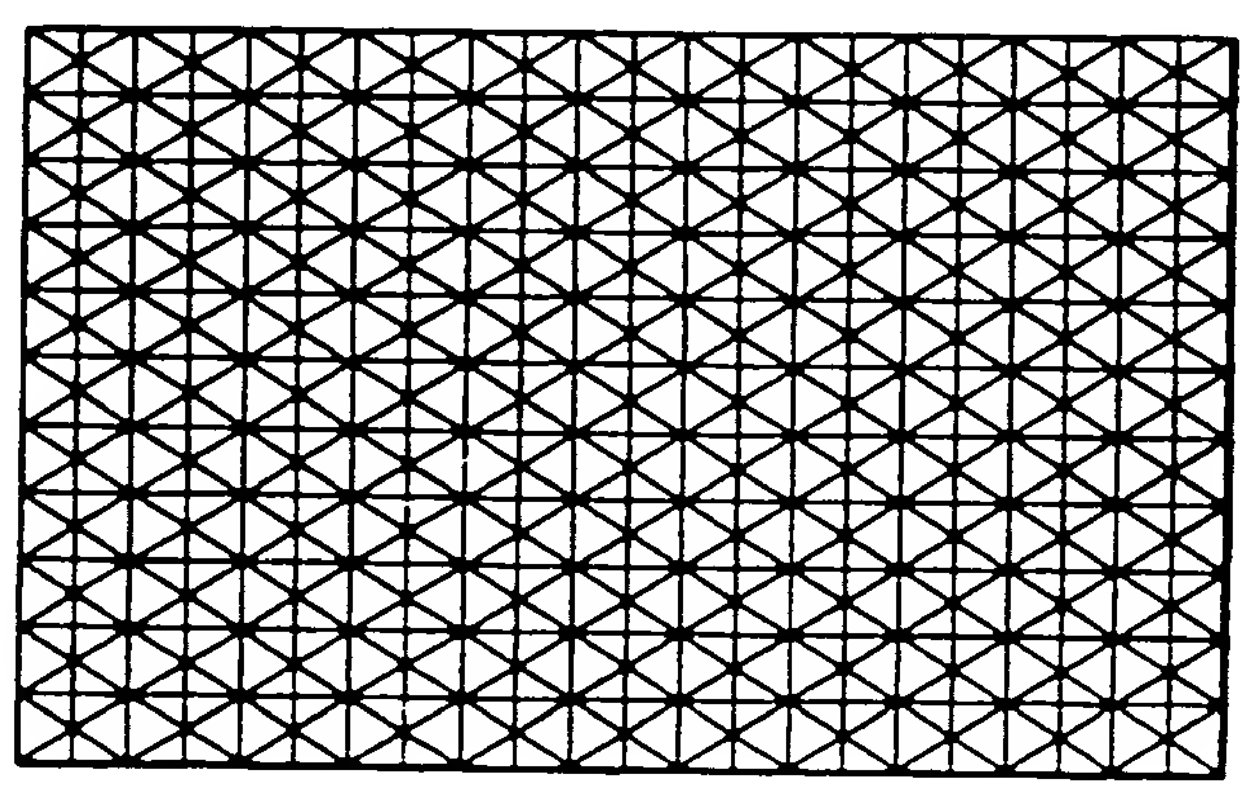
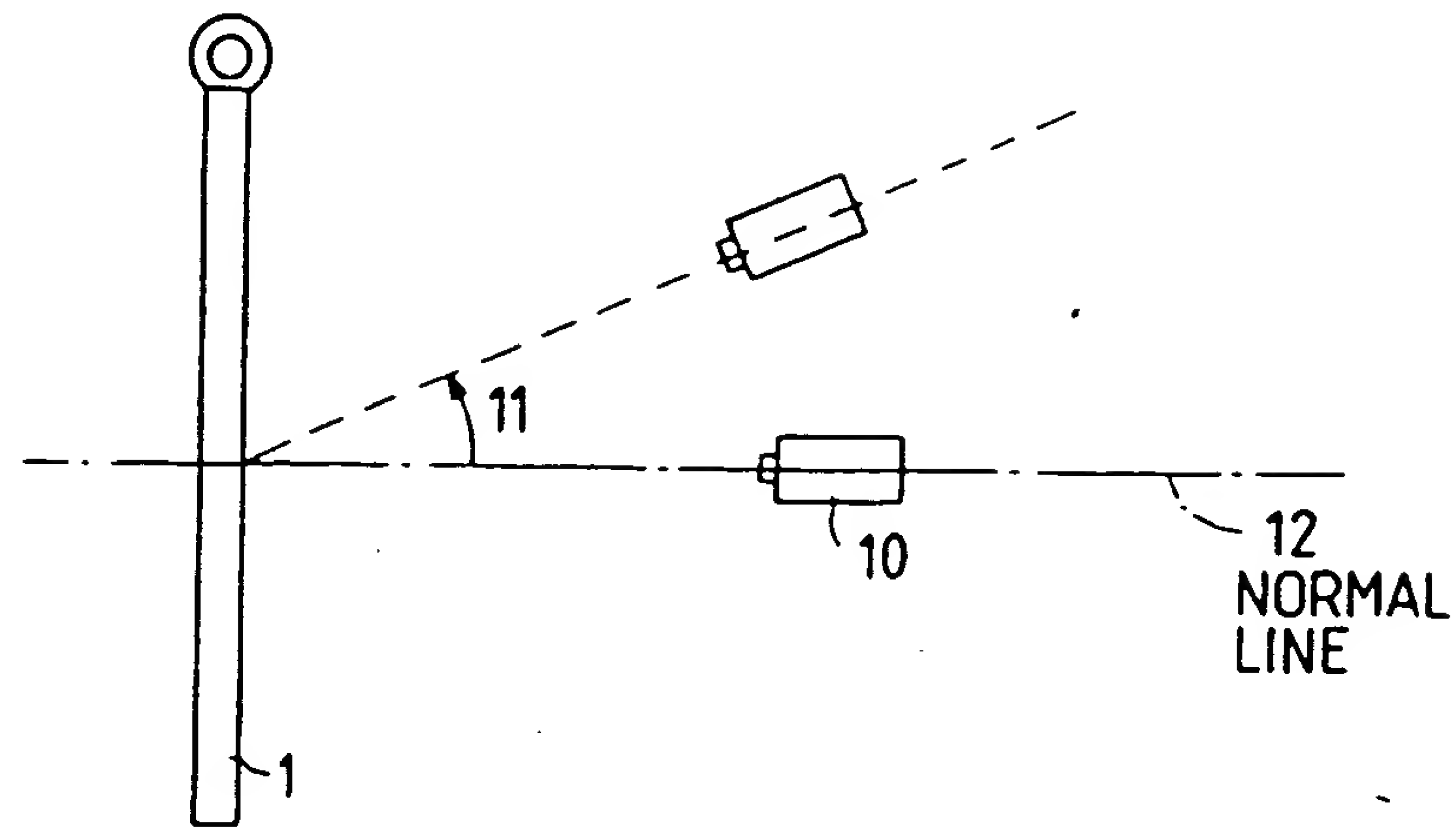


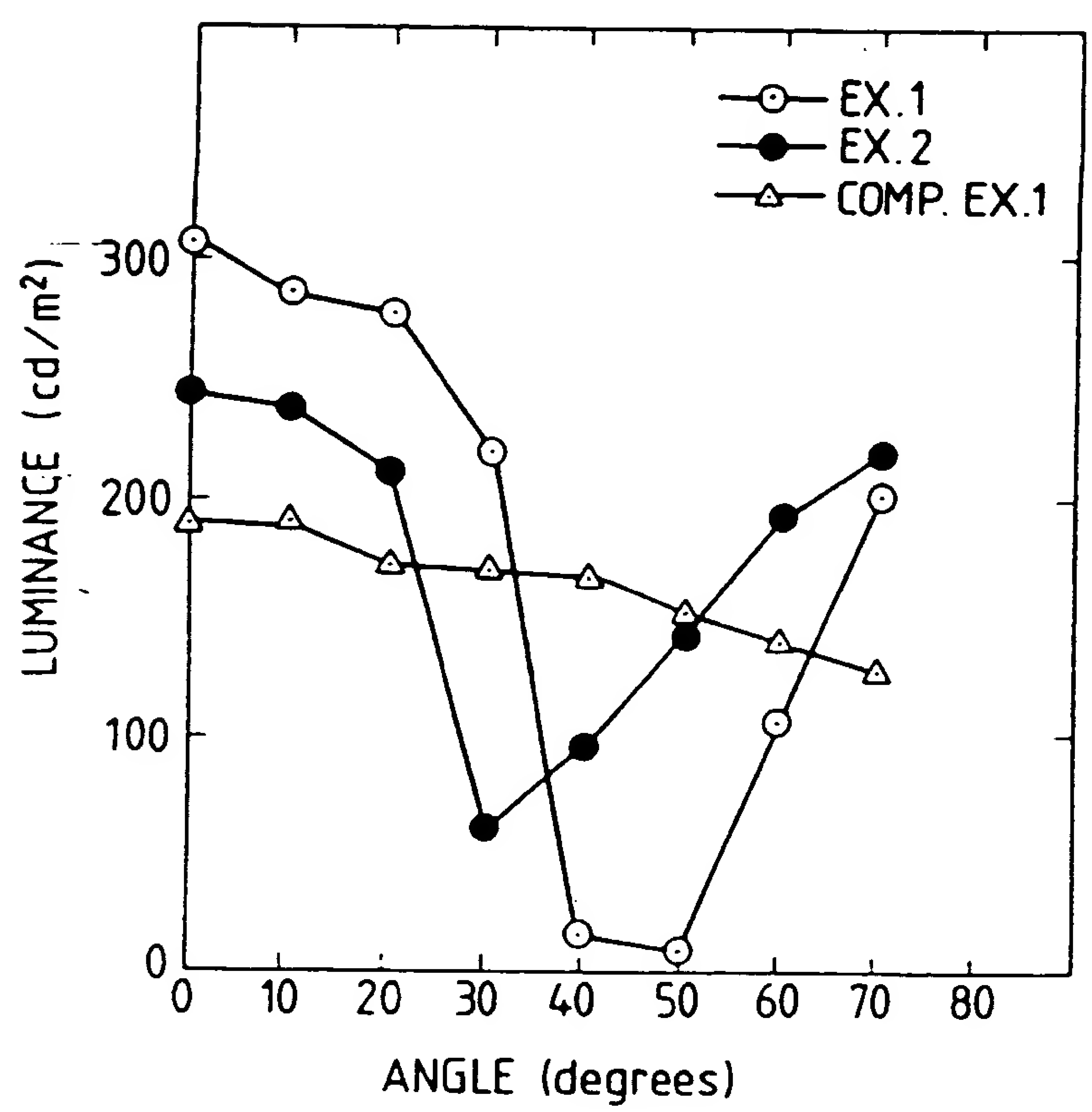
FIG. 5(c)

FIG. 6



11
10
12
NORMAL
LINE
1

FIG. 7



EX.1
EX.2
COMP. EX.1
LUMINANCE (cd/m²)
300
200
100
0
0
10
20
30
40
50
60
70
80
ANGLE (degrees)

FIG. 8

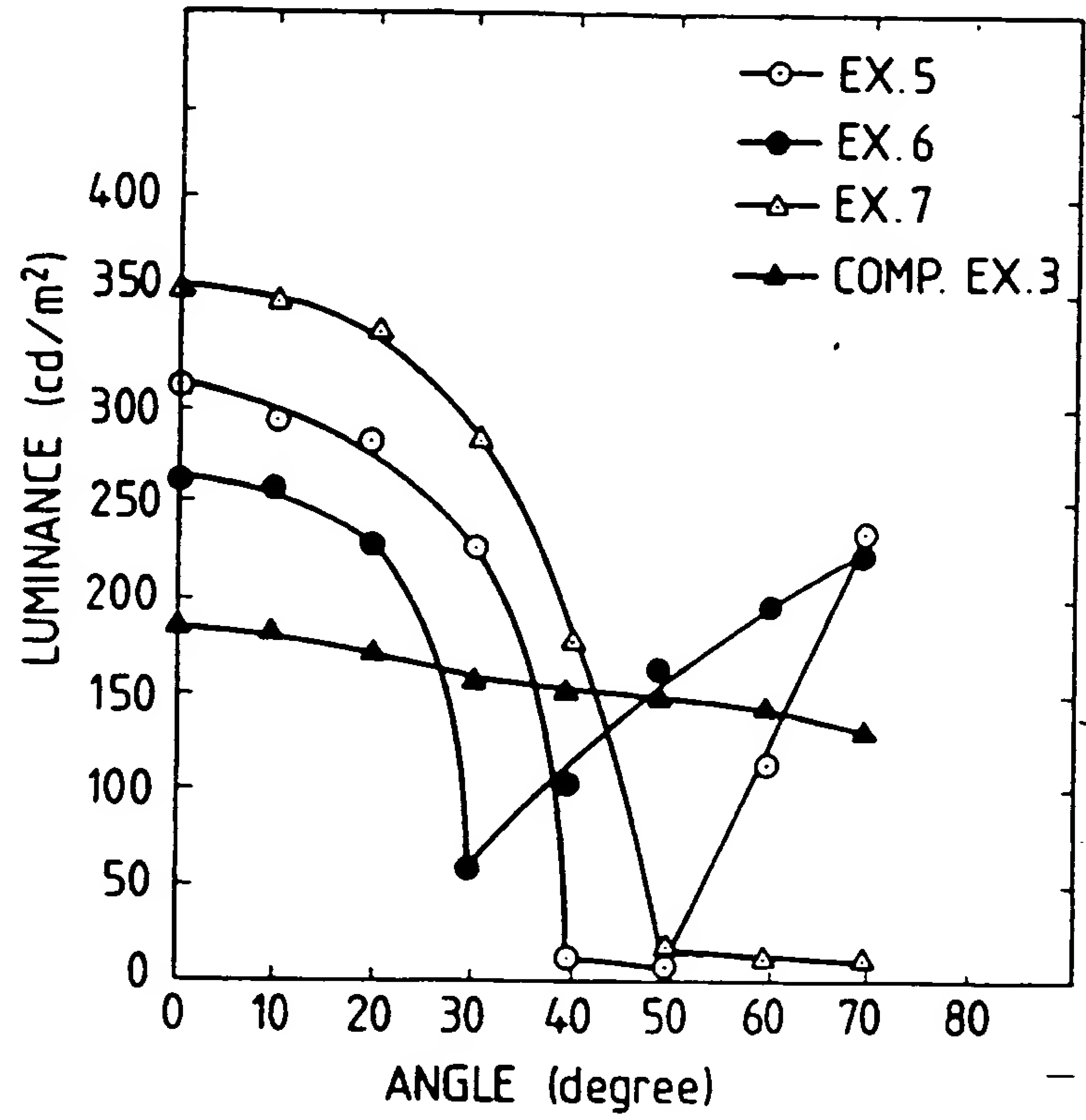

EX.5
EX.6
EX.7
COMP. EX.3
LUMINANCE (cd/m²)
400
350
300
250
200
150
100
50
0
0
10
20
30
40
50
60
70
80
ANGLE (degree)

FIG. 9

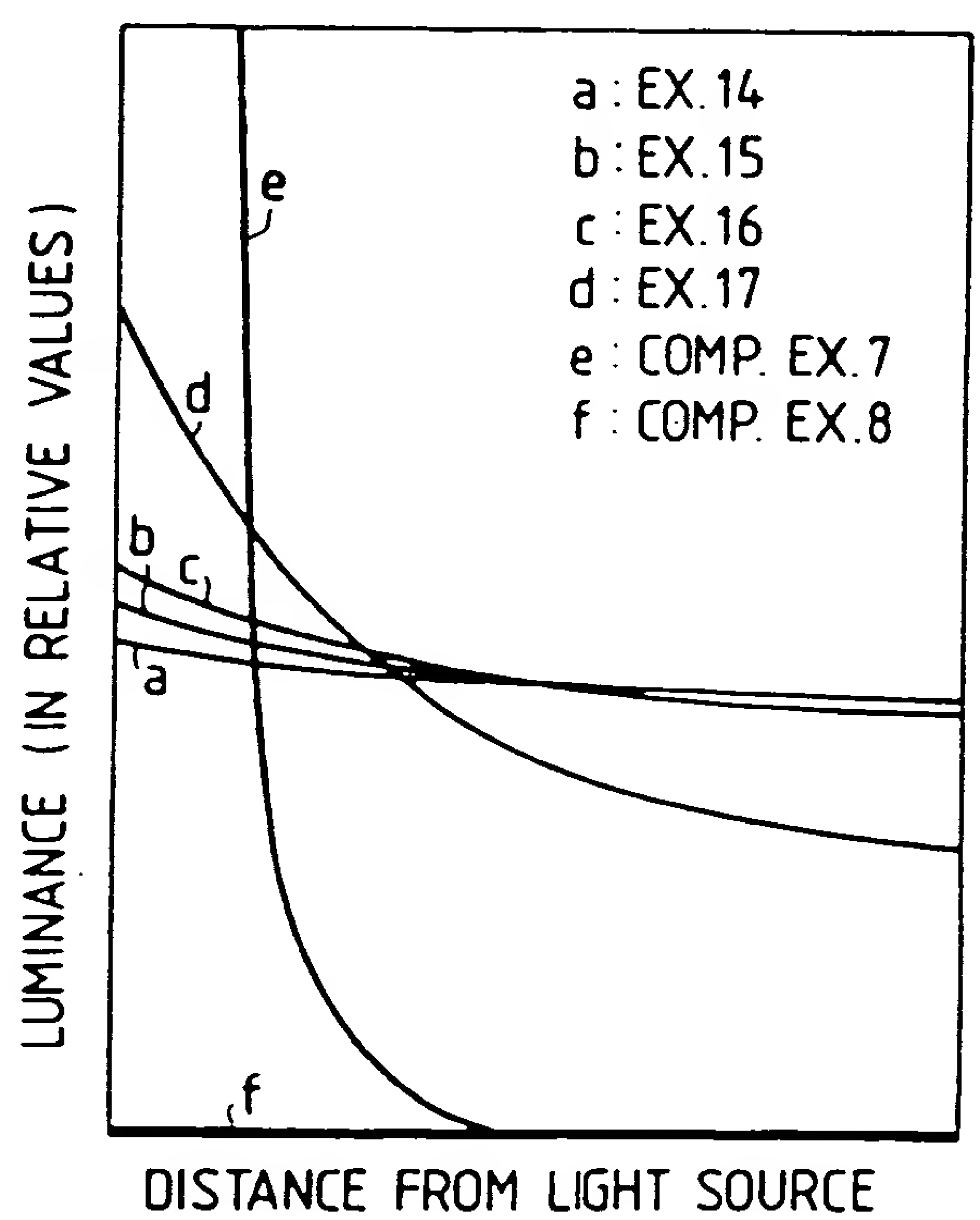

a : EX.14
b : EX.15
c : EX.16
d : EX.17
e : COMP. EX.7
f : COMP. EX.8
e
d
b
c
a
f
LUMINANCE (IN RELATIVE VALUES)
DISTANCE FROM LIGHT SOURCE

FIG. 10

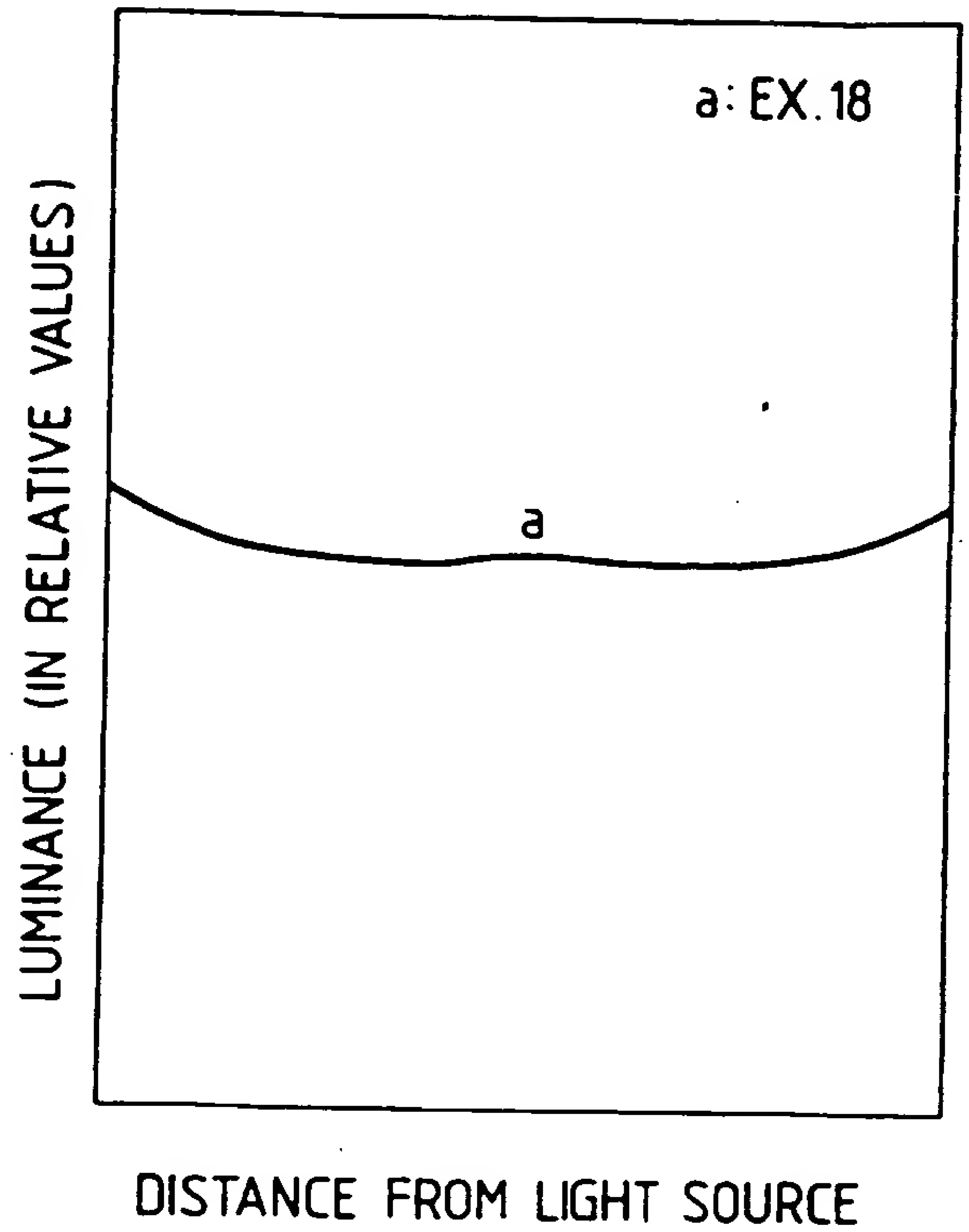
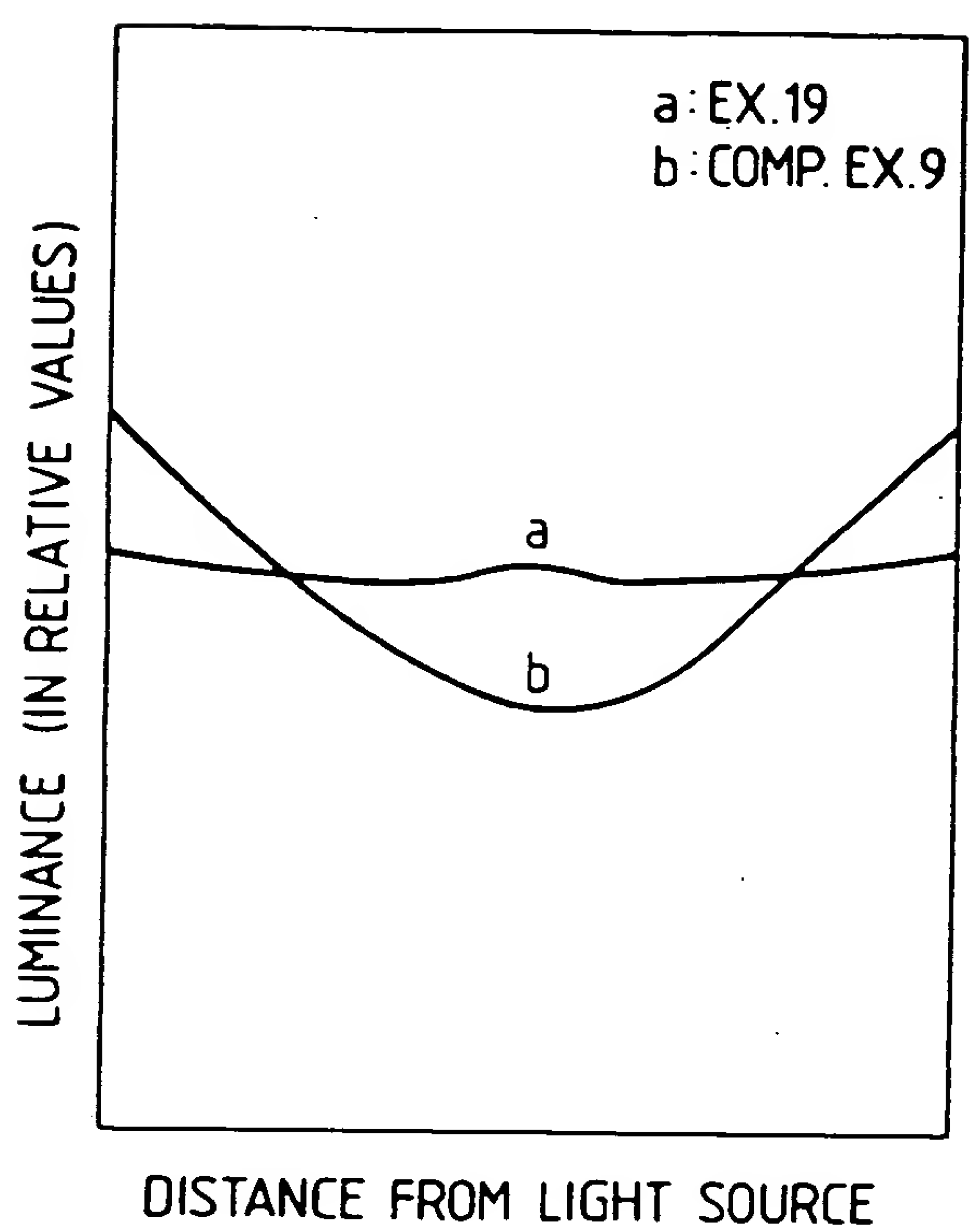

a: EX.18
a
LUMINANCE (IN RELATIVE VALUES)
DISTANCE FROM LIGHT SOURCE

FIG. 11


a: EX.19
b: COMP. EX.9
a
b
LUMINANCE (IN RELATIVE VALUES)
DISTANCE FROM LIGHT SOURCE

Japanese Published Unexamined Utility Model Patent Application (U) No. 03-069184, published July 9, 1991; Application Filing No. 01-131010, filed November 13, 1989; Inventor(s): Isamu Kaneko et al.; Assignee: Daiichi Seiko Corporation; Japanese Title: Planar Light Source Devices

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PLANAR LIGHT SOURCE DEVICES

CLAIM(S)

1) A planar light source device comprising a light source, a photo-conductor with its incident end surface positioned near the light source, a light diffusion section made on the front surface of the photo-conductor, and a reflection surface made on the back surface of the photo-conductor, characterized in that said light diffusion surface consists of two diffusion surfaces positioned with an air space between them.

2) A planar light source device, as cited in Claim 1, wherein said light diffusion section consists of diffusion surface and of transparent sheet whose front surface is saw-shaped in its sectional view.

3) A planar light source device, as cited in Claim 1 or Claim 2, wherein said photo-conductor is made of transparent resin whose refraction index n is n 1.45.

DETAILED DESCRIPTION OF THE INVENTION

(Field of Industrial Application)

The present invention pertains to a planar light source device using a photo-conductor that is used for a back light of a liquid display device.

(Prior Art)

The prior art planar light source device using a photo-conductor has such a structure as that shown in Fig. 3. More specifically, it comprises light source 1, photo-conductor 2 with its incident end surface positioned near the light source, diffusion surface 3 made on the surface of photo-conductor 2, and reflection surface 4 made on the back surface of the photo-conductor 2. While the light from the light source is entering from the incident end surface into the photo-conductor 2 and is being conducted through the photo-conductor to the side opposing to the incident end surface while being reflected at the front and back surfaces, the light is partially passing through the diffusion surface 3 and going out in form of the diffusion light. Thereby, the planar light source projects the evenly diffused light from the diffusion surface.

(Problems of the Prior Art to Be Addressed)

With the prior art planar light source device using the photo-conductor thus structured, however, the light from the light source 1 comes in from the incident end surface at any incident angle, as shown in Fig. 3, and advances while being reflected at the front and back surfaces of the photo-conductor, so the most intense light that passes through the diffusion surface 3 is the light that has an inclination angle against the diffusion surface 3. Therefore, problems arise that the brightness level is higher in the inclined direction to the diffusion surface 3 than in the direction perpendicular to the diffusion surface 3, and an image viewed from the inclined

direction is brighter than the image viewed from the perpendicular direction.

The inventors, after having experimented, found that the brightest level of the light demonstrated was in the direction of γ value, which is nearly 75° (74.6°), (as shown in Fig. 3), in case when the planar light source device has a structure shown in Fig. 3 and when the material of the photo-conductor is a transparent acrylic resin with refraction index 1.50.

The objective of the present invention is to present a planar light source device using a photo-conductor that produces the brightest light in the perpendicular direction to the diffusion surface and enables the viewers to view the brightest images from the perpendicular direction.

(Means to Solve the Problems)

The planar light source device of the present invention comprises a light source, a photo-conductor with its light source positioned near its incident end surface, a diffusion surface section made on the surface of the photo-conductor, and a reflection surface made on the back surface of the photo-conductor, and said diffusion surface section consists of two diffusion surfaces positioned with an air space between them. Because of there are two diffusion surfaces, the light going out of the photo-conductor at angle is diffused once by the first diffusion surface on the side of the photo-conductor and again diffused by the second diffusion surface. Therefore, the diffused light becomes relatively uniform, unlike the prior art one wherein the brightness was the highest in the diagonal direction, and the brightness

level and the produced images are improved in the perpendicular direction to the diffusion surface.

If the second diffusion surface of the diffusion surface section is replaced with a saw-shaped transparent body in the planar light source device having the aforementioned structure, the brightness level of the photo-conductor surface can be made higher in the perpendicular direction to the diffusion surface. As explained later in Embodiment Example 2, it is also possible to provide the first diffusion surface with a function similar to the function of the second diffusion surface thatis a refraction function of the saw-shaped section of said transparent body, to improve the brightness level in the direction perpendicular to the diffusion surface. In such a case, the back surface of the transparent sheet having the saw-shaped surface may be processed to provide the diffusion function and this diffusion surface may be positioned to face the photo-conductor surface to use this back surface as the first diffusion surface. By this, the light from the photo-conductor surface is diffused at the first diffusion surface when passing through the transparent body, is refracted at the saw-shaped section having a function similar to the second diffusion surface, and is directed in the direction perpendicular to the diffusion surface.

By thus combining the first diffusion surface with the saw-shaped section, the brightness level can be maximized in the perpendicular direction to the diffusion surface as if two sheets of diffusion sheets were used.

Moreover, the planar light source device uses a material with a low material

quality [sic; perhaps misprint for low refraction index ?] for the material constituting the photo-conductor, so the inclination angle of the light coming out of the photo-conductor surface is minimized. In addition, by two diffusion surfaces, or the first diffusion surface and the second diffusion surface with the saw-shaped section, the impact on the light caused by the inclination angle is eliminated, so the light becomes brighter in the perpendicular direction with even distribution.

(Embodiment Example)

The present invention is further explained below with reference to the embodiment examples and drawings.

Fig. 1 shows a sectional view of the first embodiment example of the planar light source device of the present invention. In the figure, 1 indicates the light source, 2 the photo-conductor, 3 the diffusion surface section, and 4 the reflection surface. The diffusion surface 3 has, unlike the prior art one, two sheets of diffusion surface: the first diffusion surface 5; the second diffusion surface 6.

In this embodiment examples of the present invention, the light diagonally going out of the photo-conductor 2 is diffused at the first diffusion surface 5, and this diffused light is again diffused at the second diffusion surface 6.

The light diffused at the first diffusion surface 5 is brightest in the inclined direction to a certain degree like that in the prior art device shown in Fig. 4 but, since the light is diffused into every direction, the intensity of the light is weaker than it was when it came out of the photo-conductor. Since the diffused light is

again diffused at the second diffusion sheet, the brightness of the light is uniform in every direction, so the brightness level is highest in the direction perpendicular to the diffusion surface.

The result of the experiment conducted by using the planar light source device of the embodiment example of Fig. 1 showed that the brightness level in the direction perpendicular to the diffusion surface was increased by 25% relative to the prior art one.

Fig. 2 shows the second embodiment example of the present invention, wherein the second diffusion surface is replaced with the transparent saw-shaped surface. More specifically, the first diffusion sheet 5 was positioned on the surface of the photo-conductor 2, and further on top of it, is positioned the transparent sheet 7 whose one surface is saw-shaped.

In this embodiment example, the surface 7a of the transparent sheet 7 that is positioned on the opposite side to the photo-conductor side is saw-shaped and has a function similar to that of the second diffusion surface. Accordingly, the light going out of the photo-conductor 2 is once diffused at the first diffusion sheet 5 and, subsequently, most part of it is directed upward by the saw-shaped section 7a, so the brightness level in the perpendicular direction to the diffusion surface is increased.

As a result of the experiment conducted by using the device of this embodiment example, it was found that the brightness level was increased by 50% in

the direction perpendicular to the diffusion surface.

In the second embodiment example, if the planar surface 7 b of the transparent sheet 7 is processed to be roughened and used as the first diffusion surface, the diffusion sheet 5 can be omitted.

If multiple transparent sheets having a saw-shaped section are used in the second embodiment example, the brightness level can be further increased in the direction perpendicular to the diffusion surface. But, this will require more number of parts and result in higher cost.

As to the saw-shape of the transparent sheet 5 in the second embodiment example, a variety of shapes can be considered. For example, θ_1 and θ_2 shown in Fig. 2 can be $\theta_1 = \theta_2$, $\theta_1 < \theta_2$, or $\theta_1 > \theta_2$. However, when there is a large difference between the values of θ_1 and θ_2, the saw-shape has an impact on the images to be viewed, which is not desirable. Accordingly, θ_1 and θ_2 are preferably equal or nearly equal. The result of the aforementioned experiment was demonstrated by using $\theta_1 = \theta_2$.

As explained above, for the prior art planar light source device of a photo-conductor, an acrylic resin is used, and the direction for the highest brightness level was 74.5°. Based on this, it can be considered that the light advancing in the photo-conductor while being reflected one after another is most intense at nearly 40° shown in Fig. 3. The angle γ at which the light with angle α goes out of the photo-conductor varies depending upon the refraction index of a photo-conductor;

provided that the α is constant, the smaller the refraction index is, the smaller the γ is.

The present invention uses this theory, so the refraction index was minimized to minimize the value of γ in order to maximize the brightness level in the direction perpendicular to the diffusion surface.

For example, when polymethyl pentene ($n = 14.5$) is used for the material of a photo-conductor, $\gamma = 68.8°$ holds true based on the following formula:

$$\sin \gamma = n \sin \alpha$$

More specifically, if $n = 1.45$ and $\alpha = 40$, $\gamma = 69°$ holds true.

The result of the experiment conducted by using said material for a photo-conductor indicated that the brightness level was highest at $\gamma = 69°$.

With the photo-conductor using a low refraction index material, the direction for producing the highest brightness level is not so much inclined from the perpendicular direction. Therefore, this photo-conductor with a low refraction index is extremely effective for the planar light source device of the present invention.

The aforementioned polymethyl pentene is merely one example of the materials, but any material can be used as long as it has high transparency, heat-resistance, and low refraction index. However, if the material satisfies $n < 1.45$, it will not be very different from an acrylic resin, therefore, is not so effective, so the material satisfying $n \leq 1.45$ is preferable.

(Advantage)

The planar light source device of the present invention produces the highest brightness level of the light in the perpendicular direction to the diffusion surface, so it enable images to be viewed to be brightest in the normal viewing direction.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a sectional view of the first embodiment example of the present invention. Fig. 2 shows a sectional view of the second embodiment example of the present invention. Fig. 3 shows a sectional view of the prior art planar light source device.

1. Light source
2. Photo-conductor
3. Diffusion section
4. Reflection surface
5. First diffusion surface
6. Second diffusion surface

DETAILED DESCRIPTION OF THE INVENTION

(Field of Industrial Application)

The present invention pertains to a back light device primarily used for the back surface illumination for a liquid crystal display device.

(Prior Art)

A publicly known liquid crystal screen of a measuring instrument or television does not have its own light, so it needs to be illuminated by a back surface reflection sheet or back surface light source. The illumination means using the back surface reflection sheet requires the surrounding brightness by the natural light or artificial light. The means using the back surface light source does not require the surrounding light but requires a dedicated luminescent source.

The light source for this purpose is required to have even luminescent brightness over the entire display sheet, so a surface light source device such as an electroluminescent device is desired. But, when a local light source such as a small incandescent lamp or fluorescent lamp is used, a device for measuring the luminescent light is necessary.

As such a light diffusion means, the device using a photoconductor is widely used (e.g., Japanese Unexamined Utility Model Patent Applications 54-8383 and 58-10-8491).

(Problems of the Prior Art to Be Addressed)

Not to prevent a thinness, which is one of the characteristics of said liquid crystal display device, its back light device is strongly required to have a thin structure. From this standpoint, the device using said photoconductor is effective but cannot uniformly diffuse the light over a broad area. Therefore, a variety of technical apparatus including the aforementioned examples have been proposed. However, every one of these prior art apparatus comes with problems. The device having a photoconductor with a unique curved surface or the device treated with masking for controlling the light transmission that requires designing and processing results in high cost, and a uniformly assembled product is not easily accessible due to uneven performance and parts including a light source bulb.

Under these circumstances, the present invention was produced with an attempt to improve a back light using a photoconductor that allows to obtain a simply structured thin and uniform product appropriate for mass production.

(Means to Solve the Problems)

To accomplish this objective, in the back light device of the present invention, a reflecting coating material is directly coated on the back surface of the photoconductor made of plastic or glass excluding a narrow zone along the end surface on the incident side, and roughness or grooves are created in the surface in the front surface that opposes to said coated surface.

Also, the reflection coating is coated on the side surfaces other than said incident side surface, which make the device more effective, and the light incident side surfaces are perpendicular to the front surface. A light-absorbing sheet such as a black delustering sheet is preferably applied to the zone where said reflection coating is not coated, or if necessary, an opaque light diffusion sheet may be placed on the front surface of the photoconductor with a space between them.

(Operation)

The photoconductor made of plastic material that receives the incident light from the side surface allows, by the reflection index of the plastic material, that the incident light having an angle higher than its critical angle advances without letting the light emit from the front and back surfaces.

The roughness on the surface of the photoconductor reflects the incident light having an angle close to its critical angle at random, so part of the reflected light goes out of the front surface while being simultaneously reflected toward the back surface by changing the reflection angle. By the light-reflection coating directly coated on the back surface of the photoconductor, the light reflected at said back surface is reflected again and advances toward the front surface. Since the reflection angle of the guided light reflected again at the front and back surfaces becomes an acute angle smaller than said critical angle, so the rereflected light heading to the front surface goes out of the front surface.

On the other hand, in the zone along the incident side surface of the photoconductor where the light reflection coating is not coated, the guided light out of the incident light that has a lesser critical angle is emitted from the front and back surfaces. The narrow zone functions as a filter to regulate the angle of the incident light into the photoconductor to a specific range (the angle larger than the critical angle in said coated area).

As a result, most of the incident light into the photoconductor goes through the repetition of the aforementioned rereflection function and is emitted in form of the light with a nearly equal light path from the photoconductor. By this light, uniformly bright light can be produced over the illumination surface.

(Embodiment Example)

Fig. 1 shows a perspective view of the device as one embodiment example of the present invention, and Fig. 2 shows its sectional view indicating that window 2 is made in the top surface of the non-transparent outer casing 1.

On the other hand, 3 indicates the photoconductor made of transparent thick sheet such as a glass or plastic sheet. On its one side surface, a tubular fluorescent lamp 4 having nearly same thickness as that of the casing body 1 and a small diameter is placed. On the top surface of the photoconductor 3, light diffusion sheet 5 made of opaque thin sheet such as a milky white color sheet is placed under the separator 6 to face said window 2.

On the top surface of said photoconductor 3, small projections in strip form 7 are positioned at random to roughen the surface. The other three end surfaces excluding the bottom surface and the incident end surface 8 where said fluorescent lamp 4 faces are coated with light-reflecting coating 9 made of white paint, which is shown by its partially expanded view in Fig. 3. As shown in Fig. 3, said incident end surface 8 is made to be perpendicular to said top surface, and the zone 3a along the end surface 8 is not coated with said coating 9. On the top and bottom surfaces of the zone 3a, light-absorbing sheet 10 such as a black delustering sheet is overlapped. And, 11 indicates a reflection sheet applied to the back surface of said fluorescent lamp 5, 12 a member for the lamp lighting circuit, and 13 an electrical power input terminal.

Another embodiment example of the present invention is not shown in the figure, but it is possible to use the light diffusion surface which is roughened by forming many small pyramids or narrow grooves. In addition, the density of the concavities and convexities constituting the roughened surface may be gradually made higher as the surface gets farther from the incident end surface 8. Also, the prior art method wherein the top and bottom surfaces formed into a curvature may be combined with said method. It is also possible to use a multiple light type wherein the opposing end surfaces of the photoconductor 3 are used as the incident end surfaces. In the embodiment example using such a structure, the major surface of the photoconductor 3 (equivalent to said window 2) can be made into a single

light type with an A5 size or a multiple light type with an A4 size, and its thickness can be 10 mm or less including the casing thickness in either instance. Once an external low voltage direct current power source is connected to terminal 12 at a time of using, arc light lamp 4 is lit by a lighting circuit structured in form of an inverter consisting of parts of the lighting circuit integrated in its body. The illumination light lit by the lamp 4 is guided from the incident end surface 8 into the photoconductor 3 by the operation of the reflection sheet 11 on the back side and advances through the photoconductor 3.

This directly advancing light is the light came out of the arched surface of the fluorescent lamp 4 on the incident end surface 8, so the direct linear direction is changed into multiple directions (shown by dotted lines in Fig. 2). First, the light ray having a large incident angle for the incident end surface 8 is reflected at surface 8 and is prevented from going into the photoconductor 3. The ray having an angle close to the incident angle capable of coming into the surface 8 goes into the photoconductor 3 once but is emitted from the top or bottom surface of said zone 3a for its incident angle being large and is absorbed by the light-absorbing sheet 10 placed in the area. Accordingly, most of the light guided into the photoconductor 3 becomes the directly advancing light having an angle smaller than the critical angle of the top and bottom surface in the region coated with said incident coating 9. Therefore, if the top and bottom surfaces of the photoconductor 3 are smooth surfaces in parallel, the light will not be emitted from both surfaces. With this

embodiment example, however, the top surface is roughened, and the guided light hitting the top surface is refracted. By this refraction, the guided light whose incident angle is less than the critical angle to the bottom surface passes through the bottom surface but is reflected at the light-reflection coating 9 coated on the bottom surface. Since the bottom surface and light-reflection coating 9 do not have an air film layer, the reflected light again goes into the photoconductor 3 with nearly the same reflection angle as said incident angle and is emitted from the opposing top surface. It goes without saying that part of the light may be reflected at the roughness structure on the surface but, for most part, the light goes through the repetition of reflection and incidence while receiving reflection from the three side surfaces of the photoconductor 3, and is emitted from the top surface.

More specifically, the guided light whose guiding angle is limited to a relatively narrow angle by the operation of the zone 3a very close to the light source hardly emits directly from the major surface of the photoconductor 3. Therefore, an inappropriate brightness level of the surface near the light source of the photoconductor 3 can be prevented. Also, since most part of the light emitted from the front surface repeats the reflection more than twice and since the reflection adds some light scattering effects to these reflections, the total light path lengths of the guided light are averaged out evenly and the light intensity after the light path attenuation becomes more uniform. As a result, the brightness level on the major surface of the photoconductor 3 can be made uniform.

Moreover, by overlapping the light diffusion sheet 5 on said surface, said uniformly bright light can be better preserved.

(Advantage)

Unlike the prior art device, wherein the generation of uneven brightness that tends to occur to the incident end surface and the uneven brightness in the broad region of the photoconductor were prevented by a complex curved structure of the bottom reflection sheet or by using a unique filter with different light transmission coefficients on the top and bottom surfaces of the photoconductor, in the device of the present invention that has a structure for taking the incident light from one side surface, the emission light from the top surface becomes the reflection light reflected more than twice in the photoconductor by not coating the narrow zone near the incident end surface of the photoconductor, limiting the incident angle of the guided light to a specific range in an attempt to improve the emission of the guided light from this zone, roughening the surface of the photoconductor, and by coating the bottom surface with reflection coating. So, the light path lengths of the emission light are averaged in the photoconductor, by which the brightness level on the major surface can be uniform. The device is simple in its structure and appropriate for mass production, by which uniform products can be presented at low cost. The device is extremely excellent in performance and can be formed thin, therefore, is extremely useful as a back illumination means for a liquid crystal display device.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a perspective view of the device as one embodiment example of the present invention. Fig. 2 shows a sectional view of the A-A section of Fig. 1. Fig. 3 shows a partial perspective view of the embodiment example of the present invention.

1. Body
2. Window
3. Photoconductor
4. Fluorescent lamp
5. Light diffusion sheet
7. Small projection in strip form
8. Incident end surface
9. Light-reflection paint
10. Light-absorbing sheet